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The Registered Office and Laboratories of the B.C.I.R.A. are:—
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Telephone : Colmore 4274-4275. *Telegrams : CIRA*

The B.C.I.R.A. Scottish Laboratories are:—
Foundry Technical Institute, Meek's Road, Falkirk
Telephone : 332

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Wetting Sand Moulds

In a letter printed elsewhere in this issue, Mr. Ben Hird rightly draws attention to the phenomenon of wetting, and recalls the important Paper on this subject given by Prof. Portevin. Appropriately we also print this week a lengthy abstract of a Paper on the subject by Daniels and Macnaughtan. Because of the volume of research work done on the properties of foundry sands, one is apt to lose sight of the physical aspects of the mould surface in relation to liquid metal. It can be taken for granted that from the point of view of appearance, also to be associated with the cost of cleaning, mould surfaces should not be excessively wetted, as this involves the adherence of the sand to the casting. On the other hand, where a mould surface is not wet in the slightest degree, it is more difficult to run thin sections, and thus the question of flowing power of the metal enters. The most significant sentence of the Daniels and Macnaughtan Paper from a foundry point of view is the one reading: "In many cases little attention has been paid to the nature of the solid surface itself, although it is clear that variations in roughness, adsorbed grease, oxygen, etc., and the presence of oxide or non-metal impurities in and just beneath the surface will affect the results." Of course, the authors had in mind metallic masses and the desirability of wetting uppermost in their thoughts. It is also stated that in practice wetting of a solid (metal) is always assisted by the use of a suitable flux. It would appear, therefore, that for large "chunky" castings, the sand walls of the mould should be free from any easily fusible impurities, whilst for the running of very thin sections where it may be essential to wet the walls of the mould cavity to avoid the casting being short run, a flux-carrying surface is indicated as being desirable. It will be recalled that where excess wetting is caused by a searching metal, a scab will be produced. The scientists have indicated in the clearest possible terms the mechanism of the problem, and the subject now awaits research work capable of practical interpretation. Sand control is now feasible; it has helped foundrymen very materially in the production of sound, saleable castings, but there is still a dearth of readily utilisable knowledge on the subject of physical and chemical interaction at the mould face. Coal dust seems a useful field for research, for whilst it does not provide grease it certainly yields tar oils, which would be of advantage in preventing excess wetting and hence scabbing, either incipient or pronounced.

Pooling Information

Little attention has been given outside Germany to a state of affairs which introduces a rather unusual situation into competitive industry. About a year ago Dr. Schacht was responsible for introducing the compulsory pooling of the experience, knowledge and technical resources of industry. The object in view is apparently to bring the poorest works up to the efficiency of the best, and it is held to be absurd that some manufacturers should be producing uneconomically through lack of information held by other firms. When there is a shortage of raw material, capital and labour, there is, so the argument goes, no excuse for avoidable waste. Such a measure naturally is not very agreeable to those who have to give, but is very much so to those who have to receive, and is regarded as almost a measure of confiscation by the former. Dr. Schacht's answer is that, by preventing the establishment of new factories, and by other measures, competition has already been checked and that the most efficient works have gained heavily from this.

All works are compelled to belong to the Organisation for Business Economy, and very detailed returns have to be made bearing on costs, organisation, technical procedure, and so on. Some industries are so completely syndicated that they have no objection to interchanging information. Indeed, it is usually provided for in the agreements governing rationalisation, and this is quite usual in this country.

It would seem that pooling of information is likely to lead to working on a completely rationalised basis, because it will tend to lead to pooling of trading results. The iron and steel and electrical industries are quoted as having progressed in the matter of pooling beyond the mere initial collection of information. While the compulsory pooling of patents without compensation has not taken place, these are regarded officially as being in the same category as other trade and technical information, as, of course, do so-called secret processes. What will be the position of a German patent owner seeking to develop abroad a process or a patent which appears to have changed its status at home; or of the foreign owner of a German patent he desires to exploit in that country?

Correspondence

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

Copper in Cast Iron

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—We have read with considerable interest the report of Mr. W. B. Sallitt's Paper to the West Riding Branch of the Institute of British Foundrymen in the JOURNAL, and would like to be permitted this opportunity of congratulating him for such a concise and informative Paper.

Referring to the section of his article dealing with the influence of copper on the mechanical properties of grey iron, I should like to add that as we know that the solution power for copper of high steel mixes of lower total carbon content, with a graphitic deposition not in excess of 2.2 per cent., is greater than that of ordinary cast iron, then the series of results obtained from such a mix would be likely to vary from the results as given in Fig. 11 of his Paper. That this is the case is shown in the table of results which follows. This table has been taken from work done by the Meehanite Research Institute on the effect of copper on Meehanite metal.

Copper. Per cent.	Brinell hardness.	Tensile strength. Tons per sq. in.	Transverse 1.2 in. dia. bar, 18 in. centres. Breaking load in lbs.	Deflection.
None	229	23.3	3,171	0.260
0.6	234	24.9	3,202	0.280
1.4	269	27.9	3,362	0.255
2.0	285	27.5	3,541	0.270
3.0	302	27.7	3,400	0.255

It will be noted that as the copper content increases so do both the tensile and transverse properties. It is admitted that the results given are applicable only up to 3 per cent. copper. It is not at all clear that additions above this amount will go into complete solution in ordinary grey iron. Iron itself will take up to about 9 per cent. in solid solution but, in the presence of carbon, solution is rapidly reduced so that in a 2.8 per cent. carbon iron particles of copper will begin to show up soon after 3 per cent. copper is reached, except where intensifying elements such as nickel, manganese, chromium or molybdenum are present.

I would like to mention that the additions of copper to graphitised irons has been covered by British Patent No. 463,145 granted to the Meehanite Metal Corporation of America.—Yours, etc.,

E. M. CURRIE.

International Meehanite Metal Company Limited,
66, Victoria Street,
London, S.W.1.

November 26, 1937.

Blackings and Coal-Dust

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—Your interesting leader, "Blackings and Coal-Dust," raises points which will give foundrymen food for thought. Does molten cast iron absorb gas from the mould or mould facings, or does the mould or facings absorb gas from the metal? Both metal and mould evolve gases, so it could be assumed there is a battle royal between the two; but the material of the mould, being much more permeable than the iron, should obviously be the loser, and the gases from the metal should force their way through the pore spaces of the mould, carrying the mould gases with them. But notwithstanding the high pressure exerted by the escaping gases from metal at elevated temperatures, we also know that gas or steam, prevented by any cause from escaping into the open air, will force back the molten metal and often blow it out of the mould through the runners and risers.

Although we know little about the selective absorption of gases, it has been established that carbon from coal smoke, given off by coal-dust additions to moulding sand, is absorbed by the mould and deposited on the sand grains, thus creating black sand. Also, some experiments were made to find out if carbon from the coal smoke was absorbed by the casting, and the results suggested that this was so, but owing to poor facilities for fine analysis the findings were not put forward as definitely established. It would be of interest if this test was made on steel castings where it should be more pronounced; it would also check the theory that the reason why coal-dust does not create a similar skin on steel castings, as on cast iron, is due to the absorption by the steel of the carbon from the coal smoke.

On the subject of coal-dust, you mention that it was demonstrated by me that coal-dust in use is converted to coke and so maintains permeability in the sand to which it is added. This should be qualified by the statement that the coking only takes place in the sand forming the face of the mould, to a depth at which the sand is raised to a coking heat (about 400 deg. C.)'; this depth varies according to the thickness of section of the casting, from a fraction on thin castings to $\frac{5}{8}$ or $\frac{3}{4}$ in. on heavy castings of 2 or 3 in. section.

Another factor which so far has received little attention and may be very closely connected with the problem of gas absorption is surface tension, or capillarity, and to anyone investigating this problem of selective absorption the French Exchange Paper by Prof. A. M. Portevin, given at Glasgow, should be helpful. Although these remarks do not deal directly with the selective absorption of gases, they are put forward with the hope of arousing further interest in this subject.—Yours, etc.,

BEN HIRD.

17, Tinwell Road, Stamford.
November 25, 1937.

New Pig-Casting Machine

A new pig-casting machine has recently been installed by Steel Engineering Industries Corporation. According to "Steel," it is of the double-strand design and replaces two old machines of similar type. Various modifications, however, have been incorporated in the new machine which, in daily operation, produce 2,000 tons of 100-lb. pigs per 24 hrs. Working to capacity the new machine costs between 9 and 10 cents per ton of pig against about 45 cents on the old machines. The scrap loss, too, is almost negligible. The new machine is of the conveyor type, and has a length of 145 ft. between sprocket centres. There are two chains to each strand, 328 ft. long. The incline is $1\frac{1}{8}$ in. per foot, thus allowing adequate height at the discharge end. Water-cooling sprays are fitted for 70 ft. of the length. An interesting feature concerns the links which, at 2 ft., are twice the usual length, thus reducing the number of moving parts. They are made of manganese-molybdenum steel.

The drive is located at the discharge end and is through a reduction gear by a 20-h.p. shunt-wound, d.c., mill-type motor. Each strand is individually driven, and the speed may be increased from 10 ft. to 54 ft. per min. Take-ups with a 2-foot travel are located at the tail sprocket, so that damaged or broken links may be speedily replaced.

Operating at full capacity, the average pouring time for 65 tons is about 15 min.

Random Shots

A correspondent from China writes of a few of the many trials and tribulations which beset the foundry managers in that part of the globe. The native worker clings tenaciously to ancestral ideas, says he, but that is a trouble not necessarily confined to China. His next trouble, however, is up quite another street, for white ants are in the habit of eating the patterns, and cockroaches have a distinct taste for core gum. A recent typhoon blew off the foundry roof, flooded the flues of the rotary melting furnace, and left the floor of the foundry ankle deep in water. In spite of all this, the foundry manages to produce considerable quantities of marine engine castings, both steam, turbine and Diesel!

* * *

The English foundryman's lot is surely a happy one compared with his compatriot in China. The atmosphere of one Scottish foundry, for instance, must be particularly light-hearted, for one moulder from Falkirk literally sings like a bird; so well that he is acquiring a professional connection in his spare time. He wouldn't chirp so merrily if he arrived in the foundry one morning to find his patterns eaten away by white ants.

* * *

Sheffield apparently is deeply conscious of a sense of the appropriate. Not content to put a stainless steel name plate on its station platforms, it has laid a glass foundation in the new buildings of the Glass Technology Department of the University. This, of course, is to allow befogged freshmen to see daylight.

* * *

It is rather a shame that so much political and commercial gain should be derived from the stamp business. The silky white hairs of that delightful child, the amateur philatelist, should not be ruffled, nor the unfurrowed brow be puckered, by vague misgivings that in buying a certain series he has perhaps furthered the success of some five, ten, or fifteen year plan of a country whose politics are entirely distasteful, and who can't play football anyhow. Danzig (such innocent looking stamps!), Russia, and now Manchukuo, are amongst those to use this method of aiding their national finances. On the other hand, it will no doubt give him a little thrill of pleasure when looking over his colonials for the hundred and fiftieth time that Barbados, at any rate, has put its profit on the sale of the Jubilee issue to the very praiseworthy use of building a new school.

* * *

If you overhear your pal remark that he had bed and breakfast in the wrong bed, do not eye him with alarm and fear for his moral well-being. He is only talking about last night's exciting game of darts wherein he scored a 26 and threw up a wrong double!

* * *

There is a tendency these days for festive seasons to start earlier and earlier. Already many Christmas numbers are out; already has Father Christmas arrived in the shops; and already diners-out have had turkey at least half a dozen times. One can then forgive the toastmaster at a dinner given recently for having announced the speaker in the following terms:—

"Gentlemen, having partaken amply of turkey stuffed with sage, we are now to have the pleasure of hearing the sage stuffed with turkey."

* * *

At yet another dinner, the host of which was a specialist on powder-metallurgy, the toast of the evening was: "Our Host, and may he never sinter." At this rate, big dinners will become quite attractive.

* * *

FRENCH WITHOUT TEARS—*II.*

Change ne'er a clout
Till May is *Août.*

"MARKSMAN."

Scrap Grinding Wheels Used as Foundry Refractories

By W. H. SALMON

This Paper gained for the author the first prize offered by the Branch-President (Mr. J. B. Allan) in a Short Paper Competition held by the Sheffield Branch of the Institute of British Foundrymen.

In many grinding shops stacks of old grinding wheels have been hoarded for years in the hope that some use may be found for them, or the abrasive-wheel manufacturer persuaded to take them back to set off against the cost of new wheels. The difficulty of removing the bond from the surface of the grains and the danger of an unsatisfactory re-bonding of grinding wheels operated at high speeds have prevented the wheel manufacturer from using this potential source of abrasive grit. It is said that the use of freshly prepared abrasive, accurately sieved, is essential to good wheel production. There are, however, numerous foundry applications in which absolute cleanliness of grain surface is not so essential.

Classes of Scrap Abrasive Available

Table I shows the three classes of abrasive scrap available. The first class consists of abrasive wheels bonded with organic mixtures such as rubber, Bakelite or resinoid compounds. The wheels are tough and are used for heavy duty, but the removal of the bond can be achieved by burning it off the grains at a red heat, after which the wheel can be crumbled in the fingers to recover the individual grains of abrasive.

TABLE I.

Classes of Abrasive Scrap.	
1. Organically-bonded wheels.	Bakelite or resinoid bond burned off at a red heat.
2. Silicate or clay bonded.	Crushed to selected grading.
3. Dust from grinding-machine dust catchers.	Magnetically separated.
Types of Abrasive Grit.	
1. Silicon carbide	Cast iron and non-ferrous.
2. Emery (alumina) ..	Steel.

The second type of scrap is the silicate- or clay-bonded wheels, which are brittle and have to be crushed. It is more difficult to obtain the individual grains, but for foundry purposes the crushed material can be graded into suitable grain sizes.

Lastly, there is the mixture of abrasive and metal dust which is collected from dust catchers. Such material contains about 30 per cent. of finely divided abrasive, which can be separated, if required, from the iron and steel dust by means of magnetic separating units. It may be of interest to note that even the metal dust from non-magnetic steel, such as manganese steel, becomes sufficiently magnetic after grinding to enable the abrasive dust to be collected free from metal. The metallurgical applications of the metal dusts will not be discussed in this Paper.

The abrasive grits used in the manufacture of grinding wheels fall into two classes:—(1) Silicon-carbide wheels for the low tensile metals such as cast iron and non-ferrous metals; (2) emery or high-alumina wheels used for higher tensile metals such as steel.

Silicon-Carbide Scrap

From the foundry point of view, the silicon carbide or carborundum scrap is more interesting on account of the high thermal conductivity compared with sand, which allows it to be used to make mouldable chills for heavy sections. It is crushed and bonded with clay or cement, or may be used without crushing by building up chill sections with pieces of scrap grinding wheels and carborundum bricks. In order to make special collapsible chills for use in situations where solid metal chills could not be permitted, the scrap is sieved to the grading of core sand and bonded with suitable proportions of clay, dextrine and core oil. The surface of the core or chill is painted with graphite to maintain the good heat conductivity and to prevent fusion of the silicon carbide with the metal. Such internal chill cores have been found useful in casting certain special steels of high shrinkage.

The use of silicon carbide for such purposes was suggested by Mr. F. Hudson in an article entitled "Heat Conductivity of Mould Materials,"* but as new brick of this type is expensive, it is claimed that this suggestion of the use of scrap grinding wheels is novel.

Table II gives the approximate thermal conductivity of various materials which have been used as chills. The comparison is shown against silica brick because the thermal data of these special moulding mixtures are not yet available for publication. The figures in the last column show the relative thermal conductivity assuming silica brick as unity, and it will be seen that cast iron is 53 times, silicon carbide 11 times, and alumina or emery 4 times as conductive as silica brick. It is interesting to notice in the case of the silicon-carbide bricks that the thermal conductivity falls rapidly as the percentage of silicon carbide is reduced from 90 to 49 per cent.

In this test the volume of the chilling material was constant; but the weight varied according to the density of the material. The copper and cast-iron blocks were cast solid, and their densities were 535 and 480 lbs. per cub. ft. respectively.

TABLE II.—*Data extracted from "Technical Data on Fuel" (H. M. Spiers).*

Chilling material.	Thermal conductivity. C.G.S. units.	Temperature range. Deg. C.	Relative thermal conductivity (silica brick as unity).
Copper	0.8580	100–837	408.0
Graphite	0.2840	0–1,000	135.0
Cast iron	0.1110	100	53.0
Carborundum brick :			
90 per cent. SiC..	0.0239	1,100	11.4
77 ,, SiC..	0.0191	1,100	11.0
57 ,, SiC..	0.0108	1,100	5.2
49 ,, SiC..	0.0093	1,100	4.4
Alundum (alumina)	0.0084	0–1,000	4.0
81 per cent. alumina brick	0.0050	1,100	2.4
70 per cent. alumina brick	0.0023	1,100	1.1
Silica brick ..	0.0021	1,000	1.0

The other chills were moulded from silicon carbide, emery and silica sand bonded with 2 per cent. Bentonite, 2 per cent. dextrine, and 2 per cent. core oil. The pieces were baked at a temperature of 200 deg. C. Naturally these chills were not so heavy as the metal chills. The silicon-carbide chill had an apparent density of 100 lbs. per cub. ft. after baking, while the emery or high alumina chill was rather heavier at 145 lbs. per cub. ft. As the intensity of chilling depends not only on the thermal conductivity but also on the weight of the chill, it will be seen that silicon carbide gives a satisfactory chill, although the weight of the chill employed was less than one-quarter that of the cast-iron chill.

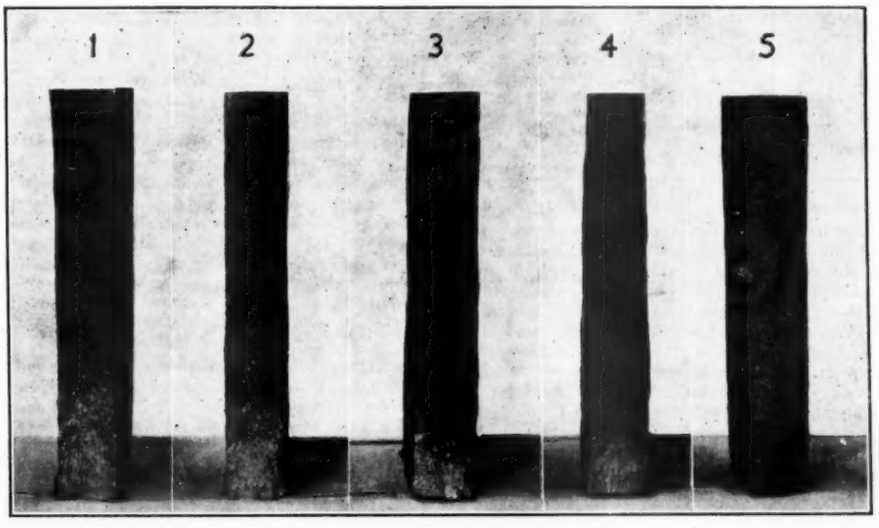

FIG. 1.—FRACTURES SHOWING DEPTH OF CHILL OBTAINED WHEN USING CHILLS OF: (1) COPPER; (2) CAST IRON; (3) SILICON CARBIDE; (4) EMERY, AND (5) SILICA SAND.

Fig. 1 illustrates the fractures obtained to show the depth of chill in a plate of cast iron, 5 in. sq. and $\frac{5}{8}$ in. thick, cast on chills 5 in. by $2\frac{1}{2}$ in. by 2 in. made of copper, cast iron, silicon carbide, emery and silica sand respectively. The plates were cast on end and the gradation of the chilling effect is as follows: $1\frac{1}{4}$ in. chill with copper; 1 in. chill with cast iron; $\frac{5}{8}$ in. chill with silicon carbide; $\frac{1}{2}$ in. chill with emery or high alumina material; no chill whatsoever with silica sand.

It has been found that the weight of the silicon-carbide chill is not so critical as it is when iron chills are used. For instance, if the chills are too light there is less danger of the metal fusing on to the chill. On the other hand, a heavy iron chill is likely to give cold laps, but this tendency is not so evident when silicon-carbide chills are employed.

The silicon-carbide scrap can be used in various forms. Where permanent chills are required, the grit is bonded with clay, moulded to

* "Metal Industry," May 12, 1937, pp. 573-5.

the desired shape and fired. If a more collapsible chill is necessary, less clay is used, and the strength augmented by core-oil additions which burn out after casting, and enable the cores to be fettled out as easily as the usual silica oil-sand cores.

Further Applications

In Table III are given some further applications of discarded abrasive materials. In the second application for foundry purposes, silicon carbide is used with a fusible bond, such as sodium silicate or phosphoric acid, so that a hard facing of the material is cast into the wearing faces of cast-iron or steel articles in order to extend the working life, or to give extra resistance to local abrasion, for example, in the edges of stair treads.

TABLE III.—*Applications for Scrap Abrasives.*

Type of foundry.	Abrasive grit.	Applications.
Cast iron ..	Silicon carbide (carborundum)	1. Chills bonded with clay or cement. Collapsible chills bonded with oil.
,, ..	,, ,,	2. Wearing faces impregnated with silicon carbide.
,, ..	,, ,,	3. Coatings for rods for welding cast iron.
Non-ferrous	,, ,,	4. Rammed furnace linings, etc.
Steel ..	Emery (alumina)	5. Mould dressings to replace silica flour.
,, ..	,, ,,	6. Shank linings.
,, ..	,, ,,	7. Steel moulding "compositions."
,, ..	,, ,,	8. Heating-element frames for electrical-resistance furnaces.
,, ..	,, ,,	9. Rammed linings for H.-F. furnaces.
General ..	,, ,,	10. Trimming oil-sand cores, etc.

In repairing iron castings, a coated welding rod is frequently used which introduces silicon into the deposited weld metal in order to control graphitisation and prevent the formation of hard spots, and this object may be attained by using silicon carbide as one of the ingredients of the coating used on the welding rods. For iron foundries making their own welding rods, scrap grinding wheels are a cheap source of the necessary silicon carbide.

The abrasive wheels in brass and non-ferrous foundries are often of the silicon-carbide type, so that the reclaimed scrap could be used as a rammed lining for the melting furnaces and air-setting cements made from the same base for patching such linings, or repairing the fire-brick faces in other types of furnace.

In steel foundries there are very few scrap silicon-carbide wheels available, because practically all the wheels used are of the emery or high alumina type. Whilst mouldable chills have been made of emery scrap, the thermal conductivity was found to be lower than silicon carbide, and it was expected and confirmed in steel-foundry practice that emery chills were not quite so effective as chills made from silicon carbide.

However, as the refractoriness of high alumina material is better than highly siliceous mixtures, scrap emery wheels and emery dust recovered from steel dressing plants have been used with success for mould dressings to replace silica flour. The high alumina mixtures, moreover, show greater resistance to certain steels which readily form silicate slags, and have been used both for mould paints and for the improvement of shank linings used with these steels. The introduction of graded emery scrap to steel-moulder's compositions has only been limited by the inadequate supplies of scrap.

High alumina material, on account of good electrical resistance and refractoriness, is employed in securing the heating elements in electric-resistance furnaces, and there is reason to believe that it would be practicable to form rammed linings of high-frequency furnaces even for melting steel by using selected grades of scrap emery. In this connection, the adulteration of the mixture by the detritus of the clay bond has to be taken into consideration. Finally, the next application is not of a refractory nature, but as a foundry abrasive. It is not suggested that foundries should make their own abrasive cutting-off wheels for oil-sand stick cores, but where trimming of hard cores is necessary in fitting up intricate moulds, steel files and tools wear very quickly, and suitable hand-size pieces of emery wheels are greatly prized by the moulder.

In conclusion, it is hoped that these few instances of successful applications may stimulate interest in valuable refractory materials which are, at the present time, being thrown on the scrap heap.

The author wishes to thank the directors of Hadfields, Limited, of Sheffield, for permission to present this Paper.

DISCUSSION

MR. J. ROXBURGH, opening the discussion, observed that the Paper impressed him as being very original and worthy of further consideration. He was particularly interested in the question of depth of chills made by the various materials. The author had given a range of copper, cast iron, silicon carbide, emery and silica sand, and it seemed to him that, from that angle, something of great interest might be discovered. The question of the thickness of the chill was not perhaps so important as some foundrymen might think. For instance, if they were making a chilled roll, the chill, providing it was sufficiently thick and strong to withstand the shock of the heat and so forth, was quite permissible to be used, but if they were to increase the wall thickness to, say, twice as much, it would have no effect on the depth of the chill on the casting. Thus the wall thickness, so long as it was sufficiently thick for strength, did not affect the depth of the chill thrown on the actual casting. Mr. Roxburgh was also interested to learn that emery was used actually in the mould, and the metal poured on to the top of it to form a wearing surface. He had heard of a case recently of a certain foundryman who applied the metal to the bottom of the mould to the thickness he wanted on the casting. He poured the metal into this mould, and a hard wearing surface resulted.

MR. F. WHITEHOUSE said that the idea of using the silicon carbide as a chill was novel to him, and one which could conceivably be of distinct use in the iron foundry. Sometimes he needed to chill wharf plates which were used in the handling of coke. They used chills on one side of these plates to ensure a longer life. He thought it might be possible to eliminate the cost of making the chills and machining them to get a good surface if they could use the material mentioned in the Paper. He would like to ask the author whether it was possible, once having used the material as a sand, to get the necessary effect continuously by remoistening the sand or adding something to it so that it could be re-used. It seemed to him that in that way a considerable improvement could be made in the manufacture of the chilled plates. He wondered if the author could say if he had undertaken any experiments in the way of constantly re-using the scrap material as one would a sand on a jolting machine. If this were possible money and a great deal of trouble might be saved.

Author's Reply

Replying to points raised in the discussion, MR. SALMON said, with regard to Mr. Roxburgh's comments, that the illustrations of the depth of chill crystals, obtained with cast iron of suitable composition with the different types of chills, were given in the Paper as it was a simple and effective comparison. A similar comparison of the effect of such denseners in promoting soundness in steel castings, in which the author was particularly interested, would have required numerous sections being prepared and photographed. With regard to the thickness of chilling material to produce specified depths of chill in cast iron, so much depended on the composition of the iron. As Mr. Roxburgh had pointed out, it was possible to increase the depth of chill to a certain limit by increasing the weight of densener, beyond which any further weight of chill did not increase the depth of the chill crystal formation. However, it would be some guide to notice that, in the illustration given, the depth of chilling for the same volume of densener was approximately one-half that given by cast-iron chills, and this was obtained in spite of the fact that the weight of the densening medium was about one-quarter that of the cast-iron densener.

With reference to the increased wear-resistance obtained by fusing scrap abrasives into cast metal faces, it was interesting to hear of the use of this method in the washing machine. No doubt there were many other applications which could be cited and which individual foundries would develop for themselves.

With regard to the two questions asked by Mr. Whitehouse as to the possibility of further recovery of the abrasive material after use in the mould and the practicability of jolt ramming the mixtures for moulds for his coke plates, there were three points to consider. First, where the chills or denseners were made very hard with sufficient clay, moulded and fired before fixing in the mould, the block could be picked out from the rest of the moulding sand after casting just as easily as cast-iron denseners are taken out, so that in this case there was a full recovery of the abrasive for further use. In the second case, which covered the use of collapsible chill cores, in which the bond was burned out during casting, there would be more difficulty in recovering such a large proportion of the abrasive material for further use, unless the core was almost surrounded by metal to hold it in the form of a pocket, from which it could be emptied or scooped out.

The third case was the use of conductive mould facings for jolt-ram moulding or any type of moulding in which a facing mixture and a backing sand were used. If the abrasive grit was considered to be just so many grains of "sand," it was apparent that with suitable bonds it was possible to make synthetic moulding mixtures to obtain exactly the same moulding characteristics, whether the base material was silica sand or abrasive grains. The abrasive moulding mixture was used as a facing sand, applied in the thickness necessary to obtain the desired chilling or densening at selected positions, and the mould was prepared as usual, except that it was advisable to use a graphite mould paint. In the case of such facing mixtures, the recovery of the abrasive after moulding and casting depended on the provision of a distinct plane of demarcation in the mould, attained by means of the difference between the facing material and the backing sand after exposure to the heat of casting.

Finally, with regard to a simple method of differentiating between the two classes of bonded wheels, the scrap wheels could be divided into the two classes by putting samples on a fire. The silicate or clay bonded wheels did not ignite, whereas the rubber or resinoid wheels burned with a large flame. When the flame subsided, the heating was continued for a short time, to burn off the carbonaceous residue, after which the wheels crumbled and the abrasive grains were collected.

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A Compact Foundry Lay-out Which Cuts Rehandling Costs*

By WILLIAM A. PHAIR

The problem faced by many foundries which melt tonnages too small to justify the installation of continuous pouring methods, yet large enough to require mechanisation to maintain competitive costs, is that of locating processing steps in a manner to avoid costly rehandling as much as possible. In short, production must flow smoothly from point to point without interruption. The fundamentals of foundry practice make this a difficult goal to reach without using conveying equipment, yet by careful planning and designing this end may be achieved, as is illustrated by the lay-out (Fig. 1) of the foundry division of the Textile Machine Works in Reading, Pa.

Built primarily to supply the iron, bronze and aluminium castings used in the textile machinery manufactured by the Textile Company, the output of the foundry has gradually increased until to-day, in addition to meeting the demands of the parent company, it also takes in a substantial tonnage of jobbing work. The building is one storey in height and built on sloping ground, permitting the erection of a railway siding direct into the cupola charging room. As a step toward reducing heavy hand labour to a minimum, industrial electric trucks are used extensively as a direct production tool, a position to which they readily lend themselves.

The foundry proper is divided into two sections—ferrous and non-ferrous. The brass and bronze melting equipment and the core ovens are located along the south wall. Immediately across the gangway are the non-ferrous moulding and core-making facilities. By consulting the chart it will be observed that bronze and aluminium castings progress by very short movements from the patternshop through the core room, the baking ovens and moulding section, to the gate cutting department. The advancement of the castings from this point to the cleaning room represents the greatest distance a casting is required to travel between production points. As grey-iron production accounts for the bulk of the foundry's output, it is obvious that from the cost angle it is more economical to move the non-ferrous castings this distance than to move the iron castings.

The Non-Ferrous Section

Bronze metal is melted in three Detroit electric rocking furnaces of 400 lbs. capacity, turning out an average of eight heats a day. Charges are composed of approximately 70 per cent. ingot metal and 30 per cent. rejected castings. In order to secure closer control on the analysis of the cast metal, no bought scrap is used. Fumes incidental to the reducing operations are drawn off by forced draft exhaust hoods mounted above the furnaces. Reducing temperatures are kept under constant observation through a panel-mounted pyrometer on each furnace. Metal is poured at 1,175 deg. C., with a 25 deg. plus or minus maximum variation permitted. Aluminium is melted in two additional electric furnaces, and, when production requires, also in two gas-fired Monarch furnaces of 150 lbs. capacity. Prevention of unnecessary waste of molten metal in warming ladles is accomplished by use of a gas-fired ladle warmer.

Grey-Iron Foundry

Grey-iron production occupies the entire northern half of the foundry. Three 72-in. Whiting cupolas, operated alternately, supply the required 50 tons of metal per day. An examination of a fractured test-bar reveals a soft, clean, close-grained iron, with an average analysis of 2.35 per cent. silicon, 0.75 per cent. manganese, 0.40 per cent. phosphorus and 0.10 per cent. sulphur. Total carbon in the metal runs about 3.50 per cent. with the combined portion averaging 0.50 per cent. Manganese deficiencies in the pig-iron are adjusted by the addition of ferro-manganese briquettes broken in two, to the charge. This practice requires constant high temperatures in the melting and refining zones in order to facilitate the union of the manganese and iron and to take advantage of the deoxidising effects of the alloy. To secure this an automatic weighing device is incorporated into a centrifugal blower to adjust the blast pressure to the varying conditions in the stack. Occasionally in special work where higher tensile strengths are desired, chrome-molybdenum alloys are incorporated into the metal by ladle additions. Here again high temperatures are required to promote the absorption of the additions. In "cold" iron the additions rise to the surface and are lost, or appear as segregations in the finished casting.

For the past several months the melter has been experimenting with small pigs in the charges, and, although sufficient time has not elapsed to permit the formation of definite conclusions, the piglets have gained favour for several reasons. One is that the charging gang prefers the lighter weight of the small pigs. Another is that the foundry foreman has noticed a definite decrease in the blast-on time required to melt a given tonnage, when smaller pigs are used, which suggests that the greater area per pound of iron exposed to the incandescent coke and hot gases promotes faster melting.

Core sand and facing are mixed in an intensive muller located in front of the core and moulding sand bins and are conveyed to the foundry via electric trucks equipped with dump hoppers. Cores are baked in oil-burning core ovens of the air recirculating type with automatic control of both the heat and the baking period. On certain types of core work callipers are used in assembling the cores to ensure identical core cavity dimensions in every casting.

Fettling

After pouring and shaking-out the day's work, the castings are loaded into large crane buckets and moved into the cleaning room. Entirely housed in, the fettling room is adapted to take care of any type casting made in the foundry. A sand-blast room takes care of the large work, while a rotary sandblast table is used for production cleaning of bronze and aluminium castings. The conventional tumbling barrel is gradually being replaced by blast-tumblers which reduce the cleaning time substantially, and at the same time give the castings a much smoother surface finish. Steel grit is gradually supplanting sand in blasting operations because of its dustless quality and the ease with which it may be handled. An unusual feature of the fettling and grinding rooms is the complete absence of overhead pipe. All dust collecting ducts are installed underground and lead to a central collecting house in the yard, where six 40-h.p. motors draw the dust into the collecting hoppers.

Large Pattern Storage Area

Beneath the eastern end of the foundry, a basement containing over 100,000 cub. ft. of space is devoted to pattern storage. Large numbered racks reaching from floor to ceiling are used to hold the patterns not in the sand. A complete card index of every pattern in the room is maintained, and before being stored away each pattern is thoroughly cleaned and shellacked, or, in the case of metal patterns, waxed. Any one of the 32,500 patterns can be located in a short time.

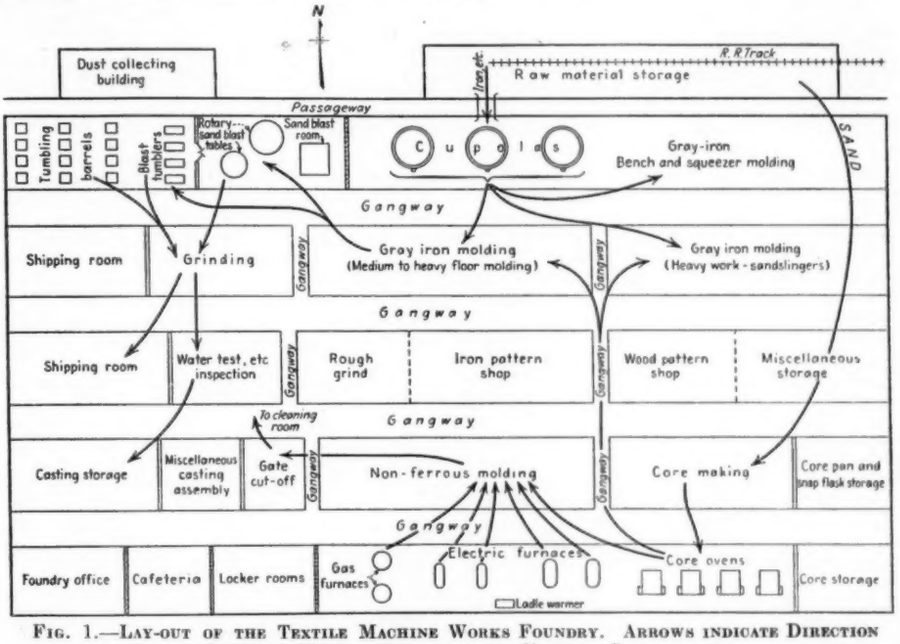


FIG. 1.—LAY-OUT OF THE TEXTILE MACHINE WORKS FOUNDRY. ARROWS INDICATE DIRECTION OF FLOW OF CASTINGS THROUGH THE VARIOUS DEPARTMENTS.

As Fig. 1 shows, the distance from the grinding section to the water test and from there to the despatch room is but a matter of crossing the gangway. In this plant departments are not separated by partitions or walls. Each department is actually a "section." Ingress and egress is possible from several sides, a fact that prevents congestion and eliminates doubling back on the line of processing flow.

An unusual method is used in testing the chambers of bronze water-meters for leaks. After passing through a rotary sandblast machine, the chambers are surface-ground and tested for porosity in the following manner: A jig clamps the open face of the chamber to a square of soft rubber. The outer surface of the casting is then painted with a soap-water solution and air under pressure enters through a hole in the rubber pad. Leaks are immediately identified by the formation of bubbles on the soap-water painted surface of the casting.

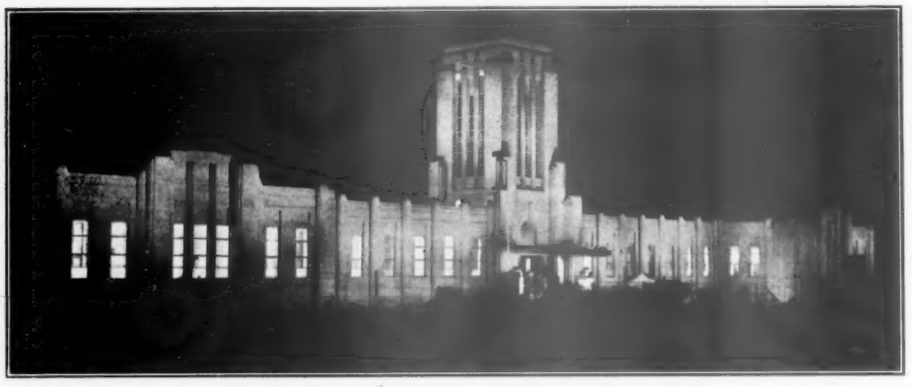
The plant set-up described enables this foundry to cast all manner of work, from small ¼-oz. castings on a match plate to heavy machine parts.

* Reproduced by courtesy of the "Iron Age."

Tata's New Laboratories

New control and research laboratories erected by The Tata Iron & Steel Company, Limited, at Jamshedpur, were recently officially opened by SIR NOWROJI SAKLATVALA, K.B.E., in the presence of a distinguished gathering.

The main building is designed with a view to meeting the growing requirements of the company and to house the metallurgical department, the chemical department, the refractories department and the technical library. It is laid out in such a manner that later on the Fuel Department may also be added, if desired.



THE NEW LABORATORIES FLOODLIT ON THE OCCASION OF THE OPENING CEREMONY.

The building has been most carefully planned to allow of an unrestricted straight line flow of work. The laboratory is built on the three sides of a square, this form allowing construction of further laboratories when required.

The method of servicing the building has been deliberately chosen as giving the greatest possible flexibility and has the added advantage that all walls are kept clear of piping and cabling. Similarly, all drainage is taken through the floors into the ducts and all piping and channelling are so constructed that they can be easily dismantled and cleaned. A departure from standard practice has been made in that all switchboards have been kept out of the laboratories and have been installed in the corridors, thus obviating corrosion of this type of apparatus in chemical laboratories.

Great attention has been paid to fume extraction and in the chemical laboratories specially-designed exhaust chambers have been installed. The working tables or benches in the various laboratories are of a new design and are so constructed that they can be dismantled, extended or modified with extreme rapidity.

The main administration block consists of the usual necessary offices for the staff, together with a conference room, a technical library and statistical office.

The metallurgical section is provided with testing rooms for routine mechanical testing and with laboratories for melting and heat treatment of steels and non-ferrous metals, and macroscopic examination. Other laboratories include a special laboratory for carrying out very delicate and specialised mechanical tests; a laboratory together with two dark rooms for investigations into the internal structure of metals and mechanical testing; a physics laboratory for determining the physical properties, cooling curves, etc., of metals, and a special laboratory for the investigation of corrosion problems, together with the necessary store rooms.

The chemical section has been provided with a series of laboratories, specially designed and fitted for different types of work, for example, laboratories for the analysis and testing of oils and paints; the analysis of raw material; analysis by combustion; analysis by electro-chemical means; a special laboratory for the analysis of non-ferrous materials, coal and coke analysis and research work on coke and coal and by-products; a laboratory for gas analysis and calorimetry, and another chemical research laboratory for special work.

The refractories research and testing section occupies an area of about 6,000 sq. ft. In the basement of the building are the sample receiving and preparing rooms, of which the pulverising room is specially built to be dustproof. Furnaces for spalling tests, load tests, fusion and slag tests are installed, and the process room will be equipped to make refractory brick on a semi-commercial scale. On the main floor the section includes an electric-furnace room and a general laboratory, adjoining which is a microscope room and a balance room.

The laboratories when completely equipped will be far in advance of anything of their kind in India and it is believed will bear comparison with the best of their kind in other parts of the world.

An Unusual Job

The job illustrated in Fig. 1 might not, in some jobbing shops, create any difficulties, but in others it would demand lengthy consideration; moreover, some foundries might even refuse to undertake it because of lack of suitable tackle, or disinclination to take the risk. This job to be described must, like all others, first be dealt with in its inquiry stages by the estimating department. It is in this department that a decision as to tackle must be settled in conjunction with the foundry. The first consideration should naturally be to decide whether or not the firm wants the job. The second is to consider whether it is possible that competing concerns will have the necessary tackle and box parts to produce the job, or either have to make these parts, which on such a casting is quite a considerable item, or have anything reasonably suited. If a firm is to have a reasonable chance of getting the order, it must assume its competitors are well equipped. Therefore, it follows if a firm has not exactly the appropriate tackle, it must improvise; otherwise the price will be too high, and all the time spent in preparing the estimate will be lost. On the other hand, if there is no tackle at all suitable, it is better to refuse to quote rather than send in a price which is altogether too high, as this is likely to create a bad impression. It must, of course, be continuously borne in mind that

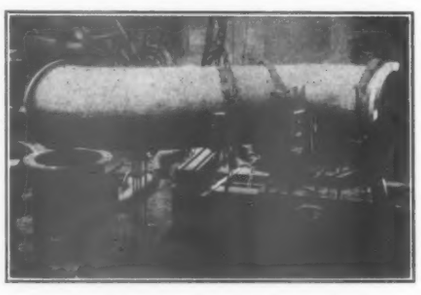


FIG. 1.—OFFSET PIPE WEIGHING 39 CWTS.

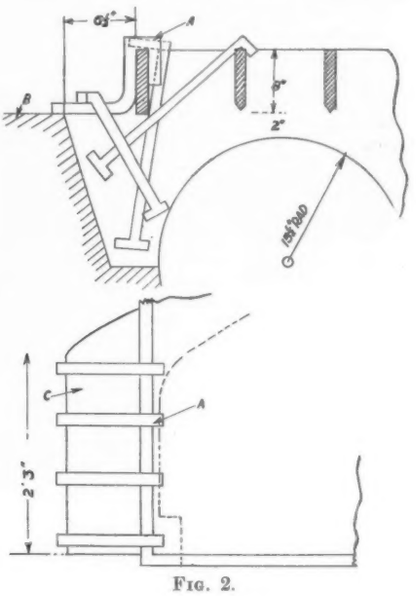


FIG. 2.

with improvised tackle the risk is really very great, and that if a waster casting result the loss could not be retrieved. The job under consideration is a large offset pipe, and the nearest box available was a top cover box 10 ft. 9 in. long, 8 ft. 9 in. wide and 8 in. deep. There was no bottom part, and this involved the job having to be put into the floor and deep jointed. The box was not wide enough even as a cover box, being 13 in. too narrow, but it was just correct in length. The result was that, on either side for about 2 ft. 3 in. the joint was outside the box by 6½ in. on each side for this 27 in. As the joint was a very deep one it made the job more difficult and more risky, due to the fact that so much sand was not only hanging, but also overhanging to a depth of 28 in., or thereabouts.

The upper sketch in Fig. 2 shows a part section through the top box which clearly illustrates the situation. It was, of course, well liftered to reinforce the structure. A shows the heavy wrought-iron special hanger on which external lifters were hung, and B is the shop-floor level. The lower sketch in Fig. 2 is a part plan, which shows the projecting portion of the joint at C. Fig. 1 shows the casting on the machine having the flanges faced. Its weight was 39 cwts.

Catalogue Received

Foundry Machinery. The Coleman Foundry Equipment Company, Limited, of New Icknield Way, Letchworth, Herts, have sent us a new edition of their catalogue. Much additional data are given of core-blowing machines, and in this direction a human touch is given by including a photograph of a bloodhound puppy using a core blown on one of these machines as a kennel. Other new sections deal with core-sand mixers core-cutting and pointing machines, abrasive cut-off machines, some new types of sand mills and conveyors. The catalogue now runs to 38 pages, is well illustrated and is available to our readers on request to the issuing house.

Wetting of Metals by Molten Metals

TINNING AND SOLDERING

A review of present knowledge on this subject, with particular reference to tinning and soldering, has been made by Messrs. E. J. Daniels and D. J. Macnaughtan in Technical Publication Series B, No. 6, of the International Tin Research and Development Council. It is pointed out that as a result of quantitative work it has been established that a general wetting is a chemical phenomenon, the forces concerned being related to those involved in adsorption. Thus, the wetting of the surface of water by many oils, previously regarded as a physical phenomenon, has been found to be due to the chemical attraction between the residual valencies or unsatisfied chemical affinities of the molecules of the oil and the water. The investigation of the wetting of solids by liquids has been mainly qualitative, owing to difficulties inherent in the measurement of the energy of solid surfaces and solid-liquid interfaces. The adhesion of a liquid to a solid, like that of a liquid to a liquid, is also determined by the chemical affinities of the atoms or molecules at the surfaces. Very little accurate information is available concerning the true chemical properties of metal surfaces, owing to the very fact that the residual affinities are generally satisfied with oxygen, grease, etc., which materials are difficult to remove even with very careful cleaning. Yet there is plenty of evidence that the attractive surface forces are of a high order, comparable in fact with the cohesive forces existing in the interior of the metal. It is well known, for example, that smooth polished surfaces of metals in contact may require considerable force to separate them, although only minute portions of the surfaces are in actual contact. The most striking illustrations of the magnitude and orientation of the forces at clean solid metal surfaces have been provided by recent studies of the structure and properties of electrodeposits. It has been shown that the structure of the basis metal may be continued in the deposit when both metals belong to the same crystal system over a wide range of lattice parameters, and also when the two metals belong to different systems. Thus electrodeposited tin (tetragonal) has been found to continue the microstructure of copper (face-centred cube), and electrodeposited copper that of beta-brass (body-centred cube). Even when there is no clear indication of a continuation of the structure of the basis metal in the coating, the forces across the junction are still considerable. Thus the adhesion of electrodeposited nickel to brass has been found to exceed 20 tons per sq. in.

These powerful forces of affinity at the surface of solid metals permit of the wetting of metals by metals for many industrial purposes. In the case of the wetting of solid metal by liquid metal, the results obtained with a given combination depend upon the procedure adopted to produce the wetting. In the present Paper the authors consider the special case of the wetting of solid metals by liquid metals and alloys of low melting point, in the presence of fluxes, excluding such processes as welding and brazing, and dealing more particularly with those cases in which the molten metal is tin or a tin alloy.

Coating by Immersion

Referring to coatings produced by immersing the solid in a bath of molten metal, it is pointed out that in practice, a wide range of coatings is produced on sheets, tubes, wire and other articles of steel, copper, bronze, etc., by immersion in molten tin (tinning), tin-lead solders (dip-soldering), and tin-containing lead (terne coatings). Mention must also be made of the production of coatings of zinc (galvanising), cadmium, etc. The mere immersion of a solid metal in a molten metal will not necessarily produce wetting. In the first place it is essential that the solid surface be perfectly clean. It is also essential that there be a degree of attraction between the molecules of the solid and the liquid at least equal to, and probably greater than, that existing between the molecules of the liquid itself, otherwise the presence of freely moving liquid molecules at the interface will by their greater attraction remove any molecules that tend to become attracted to the solid. In this respect there is a marked difference from the conditions which exist in the formation of a coating by electrodeposition, where there are no counterbalancing attractions capable of removing the deposited atoms once they become firmly attached by affinity forces to the basis metal surface. Spontaneous stripping of electrodeposits away from the basis metal may occur, due to defective adhesion when there is present a high internal stress in the deposit. In such cases it has been found that the basis metal has not been suitably cleaned. Thus it is possible to form adherent electrodeposited coatings of lead on copper or steel, whereas this is difficult to achieve by immersion of these metals in molten lead.

Intermetallic Compound Formation

In general, it has been found that wetting by hot-dipping occurs most readily where there is a strongly-marked affinity between the solid metal and the liquid metal, as indicated by the formation of intermetallic compounds or solid solutions at the interface. The formation of intermetallic compounds occurs readily in the tinning of steel and copper, and these metals are easily coated with tin. Intermetallic-compound formation does not occur readily between iron and lead, and the coating of steel with lead by immersion is very much more difficult than the tinning of steel. Wetting is readily obtained by a previous addition of a small amount of tin to the lead. The coating of copper and steel with tin-lead alloys is widely practised, *e.g.*, terne plate. Neither intermetallic compounds nor solid solutions are formed at the interface in the case of bismuth and copper, and with these metals wetting is very imperfect or does not occur. In this case also, the addition of a small amount of tin to the molten bismuth produces good wetting of copper.

The authors then go on to discuss the behaviour of coatings applied locally in the form of a drop and later discuss the wetting of joints, remarking that in practice the penetration of externally applied solder or tin into joints, such as the seams of cans, is of greater industrial importance than the spreading of solder drops. They have accordingly commenced a study of the capillary rise of tin and solders in metal tubes under the action of fluxes. Preliminary experiments have been carried out with copper capillaries 0.026 in. internal diameter (prepared by electrodeposition). After fluxing and preheating, the capillary is dipped into a shallow bath of molten tin maintained at the desired temperature in a specially constructed furnace of low heat capacity. The molten metal is then solidified as rapidly as possible by passing a blast of air through the furnace. By sectioning the capillary, it is then possible to measure both the height to which the tin has risen and its angle of contact with the wall of the tube, and so calculate the surface tension and the degree of wetting. Whilst this method may not give very accurate results for the values of the tin-flux or solder-flux interfacial tensions, the variations in the height of rise produced by varying the conditions of temperature, flux, solder composition, tube metal, etc., seem likely to provide information of value in relation to industrial soldering problems.

Notes from the Branches

East Anglian Section.—A meeting of the East Anglian Section of the Institute of British Foundrymen was held on November 18, at the North-East Essex Technical College and School of Art, Colchester. In the absence of Mr. J. L. Tibbenham, the Section President, the chair was taken by Mr. Garside, Principal of the Technical School, and a large number of members and visitors were present. The speaker of the evening was DR. A. B. EVEREST (President of the London Branch), who gave a talk entitled "Some Impressions of Modern Iron Foundry Practice in the United States." In his talk Dr. Everest reviewed points which he had found of most interest in his recent tour of the United States, and covered in his review all aspects of iron foundry practice, including general questions, such as the development of industry in the United States, questions of labour and differences in outlook among foundrymen. Coming to details of foundry practice, consideration was given to raw materials, and particularly with regard to differences between available supplies in the United States and in Great Britain, melting practice and general metallurgical technique, fettling practice, heat-treatment and, finally, the use of alloys and the development of high-duty cast irons. Dr. Everest illustrated his remarks with special reference to foundries in the motor vehicle industry, in the machine-tool and heavy engineering trades, and referring to corrosion-resisting cast irons in the chemical field. A point specially emphasised was the spirit of friendliness and co-operation seen everywhere in the United States, which is undoubtedly one of the foundations of technical progress and success.

MR. GARSIDE opened the discussion, and stressed the importance of foundry education as a basis of development, and mentioned in this connection that at his own technical school it was proposed shortly to institute classes in foundry practice. A number of further questions were asked with regard to technical details mentioned by Dr. Everest in his talk. COL. PORTWAY proposed a vote of thanks, which was seconded by MR. C. C. BOOTH. A vote of thanks was also proposed to Mr. Garside for acting as chairman and for providing accommodation for the meeting.

MR. J. L. FRANCIS, Section Secretary, presented an apology from Mr. H. H. Shepherd. He explained that it was a little unfortunate that Mr. Shepherd had not been able to be present, since it had been the intention that at this meeting Mr. Shepherd should have received the diploma which had been awarded to him by the Institute for his Paper on "The Application of Sands to the Control of Foundry Practice." Mr. Francis also mentioned that congratulations were due to Mr. Parkes for winning the second prize in the Lancashire Branch Coronation Competition.

Casting Steel Turbine Diaphragms

M. T. ANDREYEV, in "Liteinoe Delo," No. 4, 1937, refers to modern multi-stage high-pressure turbines, and says that cast-iron diaphragms or guide blade discs are only used for the low and medium pressure stages, while steel guide blade discs are used for high-pressure stages. The choice of the material for the guide blade discs, preparation of the mould and core box and also of the cores are governed by certain considerations which are discussed from the practical point of view. The pouring temperature is important and should lie between 1,510 and 1,530 deg. C. Lower temperatures result in failures due to the blades not being cast on properly and also to the formation of cavities. Higher temperatures cause uneven shrinkage and burning of the blades, although the latter phenomenon is also possible at the optimum temperature range and may be prevented by protecting the blades with sheet iron. The risers and gates should not be removed from the castings before the latter are subjected to heat-treatment, otherwise the internal stresses are disturbed.

Function of Tuyeres in Cupola Control

By J. E. FLETCHER, M.I.Mech.E.

The interesting correspondence resulting from Mr. H. V. Crawford's criticism[1] of the advantages claimed for the balanced-blast cupola has, perhaps naturally, led to further discussion on the theoretical basis on which the use of a lower row of valve-controlled main tuyeres—supplemented by two or three rows of auxiliary and smaller tuyeres above the main valved row—can be satisfactorily explained.

Mr. W. W. Braidwood[2] has outlined the probable reactions occurring in the coke bed of a balanced-blast cupola, showing clearly that between the main tuyere horizon and the auxiliary tuyere zone, CO_2 and CO are formed, the mixture of these two gases, finally, by the addition of the secondary air entering by the auxiliary tuyeres, being brought to the desired condition of complete combustion.

When designing the balanced-blast cupola the author had this sequence of reactions in mind—as shown in the patent specification—visualising the presence of CO, along with CO_2, in the main tuyere zone, and the practical possibility of burning the CO to CO_2 during the ascent of the gases into the region of the auxiliary tuyeres by means of the added secondary air. With this theory in mind he was enabled to estimate the probable analysis of the gases in the tuyere zone lying between the main valved tuyeres and the auxiliary tuyeres, the successive steps in the gasification being as shown below:—

Case (A) when the weight of air passing through the tuyeres per min. is 100 lbs.; 75 lbs. through the main tuyeres, and 25 lbs. through the auxiliary tuyeres.

Suppose the 75 lbs. of air, containing 17.25 lbs. O_2, uses one-third of its oxygen, 5.75 lbs., in forming with 4.31 lbs. of carbon, 10.06 lbs. CO, whilst the remaining two-thirds, 11.5 lbs., combines with a further 4.31 lbs. of carbon to form 15.81 lbs. CO_2. The gases resulting from the above will have the analysis

	Lbs.		Per cent. by wt.		Per cent. by vol.
CO	10.06	=	12.05	=	12.95
CO_2	15.81	=	18.90	=	12.95
N_2	57.75	=	69.05	=	74.10
	83.62				

The weight of additional oxygen supplied through the auxiliary tuyeres, required to convert the 10.06 lbs. of CO into 15.81 lbs. CO_2 must be 5.75 lbs. (in 25 lbs. air); the final analysis of the resulting gases indicating complete combustion will be:—

	Lbs.		Per cent. by wt.		Per cent. by vol.
CO_2	31.62	=	29.1	=	20.8
N_2	77.00	=	70.9	=	79.2
	108.62				

The heat values in the coke bed are shown below:—

	B.T.U.
4.315 lbs. carbon burnt to CO_2	= 62,999 (4.315 × 14,600)
4.315 lbs. „ „ CO	= 19,723 (4.315 × 4,420)
10.06 lbs. CO burnt to CO_2	= 43,278 (10.06 × 4,300)
	126,000
8.63 lbs. carbon burnt to CO_2	= 126,000 (8.63 × 14,600)

Case (B) when the weight of air passing through the tuyeres per min. is 100 lbs.; 80 lbs. through main tuyeres, and 20 lbs. through the auxiliary tuyeres.

Suppose the 80 lbs. of air, containing 18.4 lbs. O_2, uses one-quarter of its oxygen, 4.6 lbs. in forming, with 3.45 lbs. carbon, 8.05 lbs. CO, whilst the remaining three-quarters, 13.8 lbs., combines with a further 5.2 lbs. carbon to form 19.0 lbs. CO_2. The gases resulting from the above will have the analysis shown below:—

	Lbs.		Per cent. by wt.		Per cent. by vol.
CO	8.05	=	9.08	=	9.83
CO_2	19.00	=	21.42	=	14.85
N_2	61.50	=	69.50	=	75.32
	88.55				

The weight of additional oxygen supplied through the auxiliary tuyeres, required to convert 8.05 lbs. of CO into 12.65 lbs. CO_2 must be 4.6 lbs. (in 20 lbs. air); the final analysis of the resulting gases indicating complete combustion will be:—

	Lbs.		Per cent. by wt.		Per cent. by vol.
CO_2	31.62	=	29.1	=	20.8
N_2	77.00	=	70.9	=	79.2
	108.62				

The heat values in the coke bed are shown below:—

	B.T.U.
5.20 lbs. carbon burnt to CO_2	= 5.20 × 14,600 = 75,920
3.45 lbs. „ „ CO	= 3.45 × 4,420 = 15,260
8.05 lbs. CO burnt to CO_2	= 34,820
	126,000
8.63 lbs. carbon burnt to CO_2	= 126,000

Case (C) when the weight of air passing through the tuyeres per minute is 100 lbs., 85 lbs. through the main tuyeres and 15 lbs. through the auxiliary tuyeres.

Suppose the 85 lbs. of air, containing 19.55 lbs. O_2, uses 0.1765 of its oxygen (0.1765 × 19.55), 3.45 lbs., in forming, with 2.59 lbs. of carbon, 6.04 lbs. CO, whilst the remainder (0.8235 × 19.55), 16.1 lbs., combines with a further 6.04 lbs. carbon to form 22.14 lbs. CO_2. The gases resulting will have the following analysis:—

	Lbs.		Per cent. by wt.		Per cent. by vol.
CO	6.04	=	6.45	=	7.03
CO_2	22.14	=	23.60	=	16.68
N_2	65.50	=	69.95	=	76.29
	93.68				

The weight of additional oxygen supplied through the auxiliary tuyeres, required to convert the 6.04 lbs. of CO into 9.50 lbs. of CO_2 must be 3.47 lbs. (in 15 lbs. air), the final analysis of the resulting gases indicating complete combustion, as in the two previous cases:

	Per cent. by wt.		Per cent. by vol.
CO_2	29.1	=	20.8
N_2	70.9	=	79.2

The heat values in the coke bed are as follows:—

	B.T.U.
6.04 lbs. carbon burnt to CO_2	= 6.04 × 14,600 = 88,184
2.59 lbs. „ „ CO	= 2.59 × 4,420 = 11,448
6.04 lbs. CO burnt to CO_2	= 26,368
	126,000
8.63 lbs. carbon burnt to CO_2	= 126,000

It is by means of the control valves on the main tuyeres of the balanced-blast cupola that the ratio between the main and auxiliary tuyere openings can be adjusted within the limits shown in the three cases (A), (B) and (C) and beyond these when required. Such adjustments affect the composition of the gases in the tuyere zone by controlling the character of the heat evolution in the different horizons of the coke bed, made necessary in practice by the differing physical properties of the coke and metal charges during a melt or blow.

In the tables showing the heat values associated with the gas reaction in the coke bed it should be specially noted that the heat evolved when burning the CO in the auxiliary tuyere zone to CO_2 varies from nearly 35 per cent. in case (A) to 21 per cent. in case (C) of the total heat evolved when the coke carbon is entirely burnt to CO_2. It is this proportion of the total heat available in the coke carbon that is used in the balanced-blast cupola, but is lost in the ordinary cupola using a single row of tuyeres.

Whilst it is undoubtedly useful to have proper control of the weight of air supplied per minute by the fan or blower as called for by the design of the cupola, it must be realised that, especially in melts of short duration, the coke consumption per ton of metal melted is much higher at the beginning and end of the melts—demanding considerably increased air supplies.

Influence of Air Fluctuations

If and when such fluctuations of air demand are so severe that the desired uniform melting rate is seriously affected, especially when the rate falls coincidently with a fall in metal temperature, provision must be made for the supply of sufficient air to meet calls which may be in some cases 20 to 25 per cent. higher than the normal supply, which may be 15 to 20 per cent. in excess of the estimated allowance of 150 cub. ft. per lb. of coke used when, in an ordinary cupola, the weight of coke expected to be used per 10 lbs. of metal melted is one pound.

When, as in many instances, the duration of the blow is less than three hours, the ratios of metal to total coke during the first two hours are abnormally low, involving increased coke and air consumption. Such cases, when dealt with in the balanced-blast cupola, call for increased air and coke to a less extent than in the case of the ordinary cupola. But, as the increased weight of CO formed in the tuyere zone gases due to the increased air supply is associated with an increased heat evolution due to the burning of the CO to CO_2, the saving in coke during the first two hours of short melts in balanced blast cupolas is considerable. This CO to CO_2 conversion does not occur in ordinary cupolas with one row of tuyeres, for the CO in the coke-bed gases escapes in the top or chimney gases.

TABLE I.

Balanced-blast (case A).			Belden, coke bed top.			Belden, top gases.	
	Per cent. by wt.	Per cent. by vol.		Per cent. by wt.	Per cent. by vol.	Per cent. by wt.	Per cent. by vol.
CO	12.05	12.95	CO	11.60	12.10	12.13	13.0
CO_2	18.90	12.95	CO_2	18.80	12.60	18.14	12.4
N_2	69.05	74.10	N_2	69.60	75.30	69.73	74.6

Belden's Experiments

Belden's important "Tests on Cupola Gases"[3] show clearly that the gases traversing the coke bed across the horizons of maximum temperature—near the top of the coke bed—approximate in analysis to the foregoing Case (A) and seen in Table I.

It should be noted that in the Belden tests the analysis of the top gases is but little different from that of the gases in the main tuyere zone, indicating that there has been no considerable change in the analysis of the gases during their ascent from top of coke bed to top of charges at stock line. This similiarity in the analyses of the gases ascending from the top of the coke bed and in the analyses of the top or chimney gases have been repeatedly noticed in balanced blast cupola practice. The CO con-

1 FOUNDRY TRADE JOURNAL, August 19, 1937, p. 139.
2 FOUNDRY TRADE JOURNAL, September 30, 1937, p. 260.
3 Bulletin No. 54, U.S.A. Bureau of Mines.

tents recorded have been below 3 per cent. (by volume), and in one case with gases from the top of a large cupola operating on melts of long duration the analysis shown below was obtained:—

	Per cent. by vol.		Per cent. by wt.
CO	1.4	=	1.5
CO_2	18.5	=	12.7
O_2	0.6	=	0.6
N_2	79.5	=	85.2

Practical experience with balanced-blast cupolas has proved that the valved tuyere control enables the theoretical condition required for the perfect combustion of the fuel to be approached closely and, further, because the almost completely burnt gases escape to the stack at abnormally low temperatures it follows that the preheating, fusing, and superheating functions are carried out with the minimum heat expenditure per ton of metal melted.

Whilst a constant weight of air required per minute by a cupola of given tuyere zone bore can be secured by auto-control at the outlet of the fan so fitted, this control does not provide for such main and auxiliary air adjustment as will ensure complete combustion within the depth of the coke bed during such fluctuating conditions as occur frequently during a cupola melt. The auto-control can give to the fan fitted the ability to deliver a constant weight of air per minute to either a balanced-blast or an ordinary cupola with one row of tuyeres of design suited to the melting rate required.

All the air used in the ordinary cupola goes to form a gas containing 8 to 12 per cent. (by volume), of CO which, remaining unburnt to CO_2 during its ascent through the cupola, is lost in the chimney gases.

The balanced-blast cupola may use the same weight of air per minute but, as the CO gas formed in the main tuyere zone is burnt by means of the secondary or auxiliary air to CO_2 in the upper half of the coke bed, the heat evolved by burning the CO to CO_2 is saved and used in its proper function of melting.

Constant Weight of Air per Minute

The writer would remark that since the commencement of balanced-blast cupola practice the value of the principle advocated by Mr. H. V. Crawford, viz., the employment of a constant weight of air per minute suited to the lining bore of the cupola in the main tuyere zone, has been recognised, and where it has been possible to measure the kilowatt input at the fan or blower motor the kw. corresponding to the air volume when giving the best melting results has been considered as the index to the optimum air supply deemed satisfactory when aiming at a certain metal to total coke ratio.

Provided the standard air requirements of a certain size of balanced-blast cupola can be met by an auto-controlled fan there does not appear to be any objection to the use of constant air-weight fans for balanced-blast cupola service. The later manipulating of the air in the tuyere valves of the cupola, as before explained, has to do with the conversion of the CO in the main tuyere zone to CO_2 and thereby with the increase in the thermal efficiency of the cupola furnace.

Duffield Iron Corporation, Limited

A holder of shares in the Duffield Iron Corporation, Limited, has addressed a circular to other shareholders, numbering about 5,000, and a postcard asking if they are in favour of the following:—(1) Investigation of processes by technical experts appointed by the iron and steel industry; (2) investigation of value of iron ore property, proposed to be acquired; (3) removal of present board; (4) appointment of Board of Trade Inspector; (5) reorganisation of company and reconstruction of capital.

High-Duty Iron

The Paper by Mr. B. MacDougall on "High-Duty Iron—Some Experiments with the Rocking Arc Furnace," which was printed in our last issue, led to an interesting exchange of views when it was presented to members of the Scottish Branch of the Institute of British Foundrymen.

MR. E. J. ROSS (Branch-President), opening the discussion, said he wondered whether Mr. MacDougall, in speaking of future experiments, was promising another Paper at a future date. The Paper was a record of much valuable experiment. No doubt many of the members present would wish to have some of the points elaborated, but it had to be remembered that the furnace in which the experiments were made was of recent design.

Fluidity and Temperature Measurement

MR. D. SHARPE complimented the author and G. & J. Weir, Limited, upon instigating the expensive series of experiments and in placing the results before members of the Institute. A point he would like to raise was that of fluidity of the metal. Had fluidity tests such as the spiral test been taken? He thought it would be of interest to have definite figures to indicate the degree of fluidity attained, and the spiral test was of great assistance. Mr. Sharpe considered that the fluidity of the metal was almost as important as the high strength. Further questions related to the duration of soaking referred to, and what temperatures were attained and how they were determined. Did the temperatures of the nickel-molybdenum series correspond with the temperatures of the other series?

MR. MACDOUGALL said that fluidity spiral tests had not been made; he had only judged by practical tests. There had not been any difficulty in handling the metal, and he thought the running of the castings was sufficient indication of ample fluidity. As to soaking, he suggested holding the metal for sufficient time to eliminate the hyper-eutectic graphite. When running an all-steel charge 92 to 98 kilowatts were used and when superheating they purposely overloaded at 60 kilowatts in the molten charge. In regard to Mr. Sharpe's remarks on temperature determination, he thought that the question of temperatures always caused trouble. In the trials he had used a very practical test after the manner of steel smelters. A wrought-iron bar was plunged into the metal for 5 seconds and then examined. The kilowatts used were also noted, and in this way they obtained results as reliable as by the use of a pyrometer.

MR. J. ARNOTT, F.I.C., thought that it should be made clear that the electric furnace was not the only method of producing high-strength cast iron. Some of the members present were obtaining strengths of 25 tons per sq. in. and over from iron melted in cupolas. The small electric furnace had proved to be a very useful unit for making small experimental casts. He took exception to the author's remarks about machinability; he had in mind machinability of materials for some motor-cars which were a very short time in the shops and a short time on the road. In his graphs Mr. MacDougall was inclined to make a straight line between points which varied quite a lot, and obtain relationships which were not fully proved. The Paper was a helpful contribution to the technique of high-quality irons.

A Practical Test

MR. BRAIDWOOD said he had been interested in the author's method of estimating temperature, but he was inclined to think that a pyrometer should have been used. How exactly could the temperature be estimated by the wrought-iron test?

MR. MACDOUGALL replied that he used a ½-in. sq. rod, which was moistened and then plunged in the bath for 5 seconds. The length of rod melted off was then measured.

MR. R. S. M. JEFFREY, after congratulating the author on the amount of work which he had so carefully performed, said that the tensile strengths of 18 to 28 tons obtained were not exceptional. The few tests over 28 tons, notably that of 33 tons with a nickel-molybdenum addition, were specially interesting. It was, however, difficult to discuss fully the matter, because the work was not complete. His own experience was that there was very little improvement effected by nickel; he was regularly obtaining the same results without nickel additions from metal melted in the cupola. He thought the carbon plus silicon total was a more important criterion than the silicon content alone, and he was not altogether in favour of reducing the silicon and replacing with nickel and molybdenum.

MR. MACDOUGALL said that there was something to be said for lowering the silicon and replacing by nickel, but in the tests which he had made the biggest improvement was effected by using low total carbon and silicon.

Future Research Hints

MR. A. CAMPION said he had noticed the apparent lack of agreement in the total-carbon-plus-silicon figures. The same result seemed to have been obtained with totals of 6.1 and 4.2 in the tables shown. It had to be remembered that the figures which Mr. Jeffrey had given referred to cupola-melted iron, and it was possible that a different balance applied to metal melted under the conditions of the present experiments. The author appeared to be surprised at the small increase of tensile strength which resulted from the addition of molybdenum, but it was just about what the speaker would have expected. In his experience, molybdenum was not a large strength raiser, its main effect being to increase shock and fatigue resistance. If Mr. MacDougall made such tests, he thought some very interesting results might be obtained.

He was pleased to note that the author had in mind experiments on the chrome-nickel series, but he thought more useful results would be obtained from a straight-chromium or a chrome-molybdenum series; the latter was a particularly useful combination. Mr. MacDougall's experiments had been carried out in a rocking furnace, and it was an interesting conjecture as to how far the agitation of the molten metal had contributed to the results.

The BRANCH-PRESIDENT proposed a vote of thanks to the author, which was enthusiastically given.

MR. MACDOUGALL, responding, said it was his first attempt at lecturing, and he was grateful for the attention and encouragement which the members had given. He was pleased to have Mr. Campion's confirmation of the effect of molybdenum, as he had been puzzled by the contradictory nature of his own figures compared with those which he had found in Papers by some other workers. He would bear in mind the chrome-molybdenum series which had been suggested.

Committee on Lighting in Factories

The Home Secretary has appointed a Committee to review, in the light of existing knowledge and practice, the recommendations of the Departmental Committee on Lighting in Factories and Workshops, made in 1915, 1921, and 1922, concerning the conditions necessary to secure adequate and suitable illumination in such works, or in any class or description thereof, or for any particular process, and to advise about standards of sufficient and suitable lighting proper to be prescribed by regulations under the new Factories Act. The Chairman of the Committee is Mr. D. R. Wilson, H.M. Chief Inspector of Factories, and the secretary is Mr. R. W. Daniel, Home Office, Whitehall, London, S.W.1.

Cupola Practice in Textile Engineering Works*

By J. JACKSON

The object of this Paper is to outline the general principles of cupola working as practised in most textile engineering shops. Obviously, there will be slight differences in operating details between one shop and another. Actually, in the author's works such variations are disclosed as between one section of the organisation and another, though in the main, the features described can be taken as established practice. It cannot be said from a general survey of cupola working that there is anything very new in any of the textile foundries, though the practice, maybe, will raise some discussion as to the advisability of certain aspects of the process.

Textile engineers in general follow the practice of having two blows per day. The usual and best system is to have two similar cupolas, placed side by side, which are worked on alternate days. This allows of one being trimmed and patched up while the other is in operation. The average castings made are very light in weight and occupy a considerable floor space related to the metal to be cast. This is the governing factor of the practice of working two blows daily. Normally, the moulders, skilled and semi-skilled, commence moulding at 7.30 a.m., and each moulder will put on the floor, according to the type and size of the job, from three to 120 complete boxes per blow. He casts his own moulds, frees the castings for cooling off, and waters and turns over the sand ready for re-use for the afternoon's blow. There is a mid-day break from 12 to 1, and after this the morning's work is repeated and the men leave the works at 5 o'clock.

General Particulars

There are twelve cupolas, ten of which are of 3 ft. 6 in. diameter and are lined to 3 ft. 4 in. inside diameter; one is lined to 4 ft. diameter and the second one to 4 ft. 9 in. It is proposed to confine this description to the smallest size, from which the best service is obtained. These are built of ½-in. steel plates to a total height of 41 ft.; they are fitted with baffle-plate spark arresters, which divert the sparks into a concrete-lined collecting chamber built around the top of the cupola stack. The charging door is 14 ft. from the hearth, and the cupolas are so placed that the pig-iron, scrap, coke, etc., are stocked at the charging-door level, this stage being one floor above the moulding-floor level.

The wind belt is 29 in. deep by 8 in. wide. The four bottom tuyeres are each 4¼ in. by 4 in. externally and are splayed to 7¼ in. by 4⅝ in. inside the cupola case. The centre-line of the tuyeres is 2 ft. 3 in. from the hearth. Additionally, there are four top tuyeres, each 2½-in. diameter and these are set four feet from the hearth. The coke bed is 5 ft. 3 in. deep. The cupolas are blown by No. 6 S type Keith Blackman fans, taking 30 h.p. at 2,900 r.p.m. These fans are capable of supplying 4,000 cub. ft. of air per minute. For these small cupolas, this is ample, as a melting rate of 5 to 5¾ tons per hour is normally used. The size of the air-main discharge of the fan pipe is 1 ft. diameter, and it expands to 1 ft. 3 in. diameter through a length of 2 ft. 3 in. The pressure of the air in the belt is 27 in. water gauge, equal to 15.6 ozs.

These cupolas are the solid-bottom type and are cleaned at the front. They are fitted with special tilting spouts, which will hold 7 cwts. of molten metal, which is equal to a full bogey load. Fig. 1 gives details of this spout. When the cupola is in full operation, that is, yielding metal at a spout temperature of 1,230 to 1,300 deg. C., read by means of Siemen's optical pyrometer, one tapping will yield between each tap three to four bogey ladles full of the metal, each of 6 to 7 cwts.

Preparation and Working of the Cupola

The fire is lit from 6.30 to 8 a.m., according to the weight of metal required, starting off with charcoal, then scrap timber, and finally about 2½ cwts. of coke. The fire is lightly blown by means of an adjustable auxiliary air pipe, placed at the open door of the cupola, and this is continued until the coke is incandescent. Then more coke is added until the predetermined coke-bed level is reached. The fire is then blown for a few minutes longer to ensure that the coke is burning freely. The auxiliary air pipe is removed, the front door is closed, sealed, and

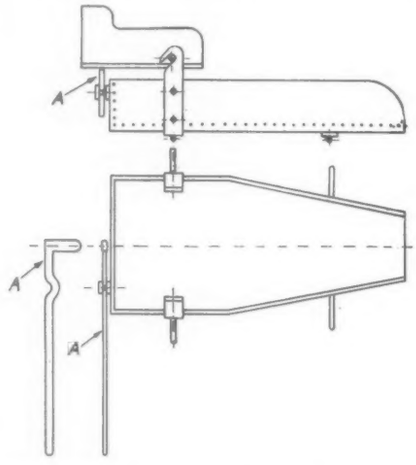


FIG. 1.—DETAILS OF TILTING SPOUT.

thoroughly packed round with red sand, the door being securely cottered up.

During this operation a number of large firm blocks of coke are wedged into the breast of the furnace, where the front door fits, and six or seven hard pieces, about 6 in. long and 2 to 3 in. wide, are firmly fixed around the bot-hole bar. This is then very firmly rammed around with sand, and particularly so against the bar used for forming the tap hole. The door having been cottered and thoroughly packed, the bot-hole bar is removed.

Whilst this has been taking place, the coke bed has been built up to the predetermined level. Charging is now commenced, and the charges consist of 10 cwts. of iron alternating with 120 lbs. of coke. During the afternoon, however, when the furnace is running particularly hot, the coke charge is reduced to 80 lbs. To every fourth layer of iron 80 lbs. of limestone is added, but during the early stages of the blow no limestone is added. The foreman gives the time for starting the fan, this being governed by the weight of metal required from the actual blow. An average melting rate of 5 to 5¾ tons per hour can be relied upon, associated with a coke ratio of 1 to 7¼ to 1 to 8½. These figures are related to the number of charges of metal; the higher the latter, the better the ratio. Coke ratio figures can be misleading, as they are often quoted whilst ignoring the bed charge.

The foreman controls the charging and melting so that the cupola is always fully loaded to the level of the charging floor, that is 14 ft. from the hearth, about 10 minutes or so before the blast is started. It is normal practice to load the first layer of iron using clean scrap of medium size, to ensure a clean start and eliminate the fear of an iron bot being formed. Practically all the earlier metal is pigged, but some may be used for casting weights, where composition is of no importance.

The metal appears about 8 minutes after the blast is put on, the tap hole being left open during this period. A longer or shorter period is an indication that the bed charge is correspondingly too high or low. When the metal is running fairly freely, that is after a further one or two minutes, the tap hole is sealed up with a clay bot. The cupola operative then strikes with a sharp-pointed rod a very small hole in the lower part of the bot to allow a faint trickle of molten iron to be continually running. This effectually prevents the formation of an iron bot in the tap hole. After a further six minutes or so, the bot is removed and six or seven cwts. of metal tapped out and pigged, as it is not considered to be sufficiently hot for textile castings.

The next tap is supplied primarily to the heavy-sectioned jobs, weights, motor bedplates, frame sides, channel rails and the like, in the order given; later on, as the metal becomes hotter, to the thinner-section jobs, and to those where it is essential to have clean and close-grained castings. There is a slag hole at the back of the cupola, which is set just below the bottom row of the tuyeres. It is opened out after the cupola has been working 1½ hrs., when all surplus slag is removed. To ensure this, no tapping takes place until a few drops of metal appear at the slag hole, which is then left open throughout the period of that particular blow. A careful watch is kept upon the slag hole, and when a drop of metal is seen to flow from it the operator taps the furnace, taking therefrom about 20 cwts., a process which is constantly repeated. By this system, a fairly regular mixing of the iron throughout the whole of the blow is secured.

Cupola Linings

During a really busy period a few years ago, daily utilising nine and ten cupolas in full blast, giving a weekly output of 650 tons of finished castings, it was found that difficulties arose in keeping the various shops at a maximum of efficiency, due, in a large measure, to the cupola practice then in vogue. The cupolas were brick lined, but, immediately below the charging door, iron bricks were incorporated to a depth of 3 ft., the object being to prevent the walls being damaged during charging. For a freshly-lined cupola, a brisk fire was maintained for two days in order thoroughly to dry and also slightly to blister and roughen the brickwork. Ganister was then daubed on the walls, making a layer from 1 to 2 in. thick; then, after further drying, the cupola was put into operation. The cupolas were patched with ganister, where necessary, to maintain the original diameter after each day's work. In spite of the exercise of the greatest care, scarcely a day passed but in one of the cupolas large pieces of ganister would be detached. This was not only detrimental to the metal but created endless trouble through scaffolding. This caused irregular melting and subsequent trouble with the quality of the casting. Moreover, every cupola in regular blast required re-bricking from the charging hole to the hearth every 12 or 18 hrs.

The iron bricks were another source of trouble, because of their expansion, which loosened the adjoining brickwork. As an experiment, a cupola was brick-lined and the iron bricks were eliminated. Though better results were obtained, entire satisfaction was not given. A cupola was then lined by ramming

* Paper read before the Lancashire Branch of the Institute of British Foundrymen, Mr. R. A. Jones presiding.

up with a special refractory material, stripping out all the brickwork completely. The work of preparing the refractory and ramming the lining occupied a week. A second week was occupied in drying the lining. This experiment was a complete failure, for, during the first blow, fully one-third of the lining gave way, resulting in one of the worst messes ever experienced.

No developments took place for a period of one year, and then a second attempt was made to ram up a lining. The same material was used, but time permitted of greater care being taken in the construction, especially in respect to venting, the workmen employed being obviously well experienced in this matter. It is now 14 years since this cupola was rammed up, and it has had no further lining added beyond its usual patching after a full day's work, and is now still in the very best of condition.

Since that time, all cupolas have been rammed up, and the current practice is as follows:—When the brickwork has so deteriorated that it is considered necessary to reline, all ganister and the loose and broken parts of the brick from the wall, particularly around the melting zone, are cleaned off, and the cupola is ram-lined on the top of the remaining brickwork in exactly the same manner as if it was the bare shell of the cupola. Cupolas so lined are proving to be as satisfactory as if they had been originally ram-lined.

Cost Considerations

The following figures may be of interest: The cupola steel shell is 59.75 in. inside diameter, which is ram-lined to 42 in. working diameter. It is lined to a depth of 14 ft., *i.e.*, from the hearth up to the charging hole. To assist the binding where conditions are most severe, a matter of 2 cwts. of calcined rock is rammed in with the other material in the melting zone. The above takes 137.9 cub. ft. of material or approximately 7 tons of patching medium at, say, three guineas a ton. Thus:

	£	s.	d.
7 tons at £3 3s.	22	1	0
2 labourers for 3 days	3	3	0
	£25	4	0

In comparison, the cost to brick-line the same cupola would be:—

	£	s.	d.
Cost of bricks	40	0	0
1 mason and 1 labourer for 1 week ..	5	5	0
	£45	5	0

Considering that the result of this expenditure of £25 4s. has now stood over 14 years and the £45 5s. item was at least repeated in 18 months per cupola, it speaks for itself.

Daily Patching

The question of the daily patching to make good the walls which have been partly burnt away in previous day's working is important. The practice of working two blows per day, which is deemed to be desirable in a textile engineering foundry, is certainly very punishing to the walls of the cupola. Thus the figures in Table I are interesting. They relate to a test made in May, 1927, on cupolas Nos. 3 and 4 in the No. 4 Foundry.

TABLE I.—*Daily Quantities of Ganister and 50 : 50 Mixture used for Patching.*

Ganister.	Cwts.	50 : 50 Mixture.	Cwts.
Wed., 11.5.27 ..	23	Thurs., 12.5.27 ..	12
Fri., 13.5.27 ..	23	Sat., 14.5.27 ..	14
Mon., 16.5.27 ..	19	Tues., 17.5.27 ..	13
Wed., 18.5.27 ..	20	Thurs., 19.5.27 ..	14
Total ..	85	Total ..	53

Table I discloses a saving of patching of 37.6 per cent. by weight, yet the money saving here on purchase of patching material is not great, due to the higher price of special patching material against ganister. The saving was only a matter of £5 on 100 tons of material, but there is the saving of less patching material being burnt off the walls of the cupola, which simply washes through the molten metal, and even if all collected with the slag, it is certainly not in any way beneficial to the metal. Further, time is saved in having a less amount of patching material to be applied, and, in consequence, the cupola is dried more rapidly. Moreover, the cupolas are worked at a much cheaper rate in respect to patching material, as it has been found by trial that 75 per cent. ganister and 25 per cent. special patching material well milled in with the ganister is giving equally good service as when a 50/50 mixture was used. The cost of this now works out:—

	s.	d.
Daily cost of patching material per cupola =	17	10½
When using ganister only =	24	5½

Charging the Furnace

The charges for calculation purposes, etc., are based on 2 tons, though these are always divided into four, with a coke split between, so actually the charges are 10 cwts. each. These are made up according to the class of casting required from 2 cwts. of pig and 8 cwts. of scrap to 5 cwts. of pig and 5 cwts. of scrap, with, at times, addition of scrap steel up to 25 per cent. When steel is added, the iron scrap is reduced in proportion. The following are typical charges now being used (Table II).

The finished castings are the same as the return scrap, though the alteration to carbon due to annealing should be noted.

TABLE II.—*Typical Charges.*

	G.C.	C.C.	Si.	Mn.	S.	P.
8 cwts. various brands of No. 3 foundry pig	2.99	0.34	2.65	0.725	0.035	1.04
16 cwts. return scrap	3.06	0.41	1.98	0.45	0.098	0.98
16 cwts. bought scrap	3.1	0.45	2.15	0.50	0.08	0.90
Melting charge allowance	—	—	−0.20	−0.07	+0.02	+0.02
Finished castings	3.065	0.41	1.98	0.458	0.098	0.98
A Second Mix.						
12 cwts. various brands of No. 3 foundry pig	3.06	0.43	2.52	0.86	0.037	0.634
14 cwts. return scrap	2.97	0.43	1.93	0.557	0.09	0.78
14 cwts. bought scrap	3.1	0.45	2.15	0.50	0.08	0.90
Melting charge allowance	—	—	−0.20	−0.07	+0.02	+0.02
Finished castings	2.97	0.43	1.93	0.557	0.09	0.78
*Third Mix.**						
14 cwts. pig	3.35	0.46	2.44	1.0	0.04	0.20
14 cwts. return scrap	3.45	0.36	2.04	0.86	0.08	0.24

* This has been included as a matter of interest, which is one of the special cases found in all works. For one particular class of work, this mixing has been in use unaltered for over 3 years and is in daily use.

Coke is charged in riddles each holding 40 lbs. Taking a normal day, coke as supplied is used up as follows: for early morning firing of the cupola, 9 riddles, and for making up the bed 13, or together 880 lbs.; for the morning blow, 9 charges at 12 riddles per charge equals 4,320 lbs.; for the afternoon blow, 13 riddles to make good the bed, or 520 lbs.; for the afternoon blow, 8 charges at 10 riddles per charge, or 3,200 lbs.; total for two blows per day, *i.e.*, 17 charges equals 8,920 lbs., or for 34 tons metal melted a matter of 4 tons of coke, which gives a ratio of 1 to 8.5.

The above results are obtained using patent oven coke, which has the following composition:—

Carbon, per cent.	86.99 to 89.00
Ash, per cent.	8.0 to 9.0
Sulphur, per cent.	0.55 to 0.61
Moisture, per cent.	0.5 to 1.0
Volatile matter, per cent. ..	2.0 to 2.4

The limestone used analyses out as follows:—

Calcium carbonate, per cent. ..	94 to 96
Silica, per cent.	0.5 to 2.0
Alumina, per cent.	1.25 to 2.75
Carbonate of iron, per cent. ..	0.5 to 2.5

During the last two years in particular, much has been written about metal costs; furnace costs; melting costs, etc., and, particularly, about costs and value of return scrap. It is not intended to enter into any controversy about this, though personal conclusions may be of interest. For instance, the following figures may be taken to represent the cost of material bought and delivered to the foundry yard, viz.:—

	Last February. Per ton.		At present.	
	s.	d.	s.	d.
Pig-iron	78	0	109	0
Bought scrap	60	0	85	0
Coke	31	6	33	0
Limestone	8	4	9	0

Thus the cost per ton of input works out as:—

	Shillings.	Shillings.
4 cwts. pig at 78s.	15.6	21.8
8 cwts. scrap at 60s. ..	24.0	34.0
8 cwts. return scrap at 94s.	37.6	48.0
Furnace labour cost ..	7.46	7.46
Coke at 1 to 7 ratio ..	4.5	4.70
Limestone, ¼ cwt.	0.2	0.20
Ganister, etc.	0.75	0.84
	90.11	117.00
4 per cent. melting loss raises this to	93.86	121.8
Blower power	0.20	0.20
Output of 1 ton	94.06	122.00

One might say the figure given for domestic returns, gates, runners, faulty castings, etc., *i.e.*, 94s. per ton, is far too high, as they could never be sold at this figure. Consider one is compelled to remelt this in a proportion such as above given. It has cost 94s. per ton at output of cupola. Consequently, that is the figure it is necessary to be based on to compile the true figure of cost of metal at the spout.

Most writers on iron melting assert that 30,000 cub. ft. of air is required to melt 1 ton of iron in the cupola. Now consider a moment the figures outlined earlier in this Paper. The small cupolas melt 5 to 5½ tons per hr. The Keith Blackman fan will supply 4,000 cub. ft. of air per min. This equals a supply per hr. of 240,000 cub. ft. This is sufficient for a melt of 8 tons per hr. and quite ample for the small cupolas. It was stated that there was also available a cupola of 4 ft. 9 in. inside diameter in which iron is melted at the rate of 12 tons per hr. This cupola is blown with a Keith Blackman fan exactly as used on the smaller cupolas, which fan will give 240,000 cub. ft. of air per hr. Yet 12 tons of iron melted requires 360,000 cub. ft. of air. Where do the other 120,000 cub. ft. of air come from? Is local air of such quality 30,000 cub. ft. is needed to melt 1 ton of iron?

Another rather interesting point in cupola working is the great attention and stress given by various writers to having the correct ratio of tuyere area to the area of the cupola. This has been often given as 1 to 5. Such stress was

laid on this point when the No. 4 foundry was built in 1921, that the four new cupolas installed at that time were each fitted with tuyeres giving this ratio. This was tested out for many weary months without satisfaction, the iron was never sufficiently hot, melting was very slow, the castings were "blown" and oxidised. These were altered to small-size tuyeres which have a ratio of 1 to 14.6, and since this no trouble in this direction has been experienced. It should be stated, however, that an alteration to the tuyeres has been effected.

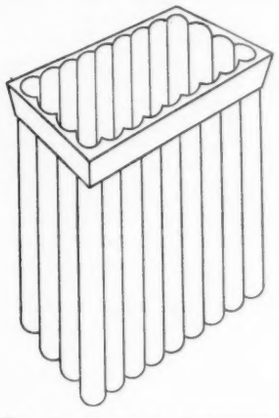


FIG. 2.—SHAPE OF ANNEALING POTS.

They now have a ratio of 1 to 10, and rather better results are now being obtained than from the 1 to 14 ratio.

For tuyere ratios, the figures usually given are, for cupolas 24 to 36 in. diameter, 1:4 to 1:5, and for cupolas 48 to 60 in. diameter, 1:7 to 1:8. These ratios have been found to give most efficient melting according to a large number of people. If the ratios are increased or decreased and one of the other variables, such as blast pressure, adjusted accordingly, the same results can be obtained. The number of rows of tuyeres is a debatable point, which has never been settled.

There is much to be said for the principle of one row, for the following reasons:—It is the heat generated by the burning of the carbon in the coke which melts the iron. To burn that carbon requires a certain amount of air. Now from thermo-chemical determinations, it is known that carbon burning directly to CO_2 generates 14,500 B.T.U. of heat, while C burning to CO generates only 4,500 B.T.U. Thus, maximum thermal efficiency is obtained when the carbon is burnt entirely to CO_2 in one stage.

It has been calculated that there is a loss of efficiency of 38 per cent. when it is burned first to CO and then further oxidised to CO_2. The requisite amount of air can be got through one row of tuyeres, and the employment of an upper row of tuyeres to combust any CO formed should not be necessary. It is still a very doubtful point if an upper row of tuyeres does convert any CO to CO_2, because CO is not converted to CO_2 above 700 deg. C. or below 400 deg. C.

Annealing Iron Castings

In a normal week's work, in a large textile engineering works, 320,000 to 600,000 castings will be produced. These are annealed for the purpose of eliminating all hard spots; for promoting facility of boring, turning, milling, drilling and screwing at reasonably high speeds. These castings, as-cast, vary in analysis according to their employment, and many of them are $\frac{1}{8}$ to $\frac{3}{16}$ in. section. The necessity for softening these castings to enable them to be machined at all, is apparent, for it is essential to machine such quantities at reasonably high speeds; hence the particular care necessary in annealing efficiently. For the system of annealing there are two batteries of coke-fired ovens, with six ovens in each battery. Each oven will take six cast-iron annealing pots, each capable of holding from 1 cwt. to 4½ cwts. of castings, varying according to type. The castings are packed in regular layers in the pots. Between each layer of castings and surrounding the whole of the castings is packed a mixture of dry cast-iron borings and the black oxide scale collected from the drop-forging department. Six of such pots are placed in each oven, the door is closed and sealed air tight with loam or ganister. The ovens are then heated until after seven hours' firing on a very regular system to prevent any temperature drop the temperature is 830 deg. C.

Materials such as blocks, bar fingers, roller stands with brass plugs, nuts, spindle catches, separators, etc., are heat-treated within a temperature range of from 750 to 850 deg.

The temperature is kept very steady for a further period of seven hours, never allowing it to exceed 850 deg. C. nor go below 830 deg. C. After this, it is allowed to fall gradually, until after a further seven hours it has fallen to anything between 600 and 700 deg. C. The oven doors are then broken open, the pots removed and immediately placed under a sealed shed, free from drafts, and left a further 24 hours gradually to cool off. The castings are then ready for the machine shop and are, as stated, very readily machined at high speeds after such treatment. A constant check is kept on these ovens for correct temperature by means of the Cambridge-type optical pyrometers, taking the readings through small portholes placed on the sides of each oven.

The annealing pots used are very strongly built on the wave line system; these are cast from the lowest phosphorus pig available, which gives 12 months' service per pot. If cast with 1.0 per cent. phosphorus, the pots would be cracked and burst in less than a month. These pots are 2 ft. inside length, 1 ft. wide, and 1 ft. 8 in. deep. Fig. 2 indicates general shape.

To indicate the care taken to keep the temperature of these ovens regular, the system of firing is controlled as follows:—It is set out as a chart for the guidance of the men. Commencing at 6 a.m., the fires are cleaned out; the dampers are opened at full at the fire door, and the draft slides are set 2 in. open. While this is being done, two other men are drawing the pots from the ovens and are re-charging by 6.15 a.m., after which they lute up around the oven door, etc. At about 8.0 a.m. seven to eight shovels of coke are added. The back of the oven is now examined to ensure that the doors are properly sealed. At 8.30 a.m. a further six shovels of coke are charged. The fire is now allowed to burn bright until 9.15 a.m. Then six more shovels of coke are added, and another six at 9.45 a.m. At this time, flames start shooting under the firebox cover; when this happens the fire-door slides are set to be only ½ in. open, or less, until flames cease to show.

(*Concluded on page 442.*)

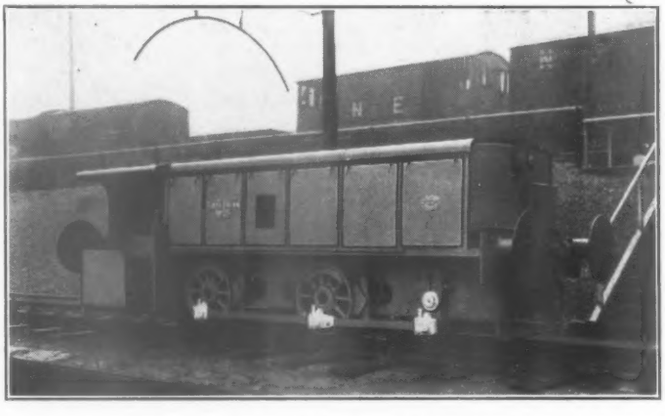
Diesel Reversing Locomotive

DESIGNED FOR STEELWORKS USE

The locomotive illustrated has recently been supplied to Messrs. Thos. Firth & John Brown, Limited, by Messrs. Robert Stephenson & Hawthorns, Limited, for service in their steelworks, and was built at the maker's Newcastle works. This locomotive is for arduous service, being required to draw chiefly concentrated loads on a single heavy bogie, which is a very different proposition from handling a train of wagons where the load against the locomotive is built up gradually as the draw-chains between the wagons tighten; consequently starting effort and reliability are essential features. It is restricted in height so that it can handle this traffic through a low tunnel which lies between the extremes of the area over which the locomotive has to operate.

This, it is claimed, is the first time that a Diesel engine of the reversible type has ever been used for traction purposes in a locomotive. The reversal of the engine is effected by means of compressed air. In other words, the engine is of the direct-reversing type and once it has been started it runs equally well in either direction of rotation. The starting, stopping and reversing are all controlled by means of a single hand-wheel. In addition to the hand-wheel, the engine is equipped with a speeder lever which, through the variable-speed governor, controls the engine from full speed down to a tick-over speed. These controls, etc., are duplicated so that the locomotive can be driven from either side.

The engine is of heavy-duty design developing 110 b.h.p. in four cylinders at 500 r.p.m. It is a Crossley scavenge-pump Diesel and is fitted with detachable liners. The low revolutions and general design make it particularly suitable for heavy-duty shunting. In spite of its slow speed, the engine is compact on account of the cycle upon which it operates. This latter factor also gives the engine a very smooth regular torque. Full torque is maintained over a wide speed range.



VIEW OF DIESEL REVERSING LOCOMOTIVE.

One of the great advantages of this type of engine for shunting work is that stand-by losses are eliminated. Thus, whenever the locomotive itself is not actually moving, the engine is at rest. This not only makes for an appreciable saving in fuel consumption, but also means that exhaust gases are not discharged into the atmosphere while the locomotive is waiting for its load. This may be a substantial advantage in enclosed premises. Westinghouse straight air-brake equipment is fitted and arranged to take air through reducing valves from the engine starting bottles. The main fuel tank is carried in the cab and fitted with communications to the engine scavenge air manifold to provide the necessary pressure to the feed pumps. The fuel tank has a capacity of 45 galls. The locomotive is of the 0-4-0 type, the wheels being 3 ft. 1 in. dia. and the wheel base 6 ft. 3 in.

CENTENARY CELEBRATIONS were held in connection with the mines of the Vieille Montagne Zinc Company, Nenthead, Cumberland, on November 20. The Vieille Montagne Company purchased the Nenthead group of lead and zinc ore mines in 1896.

The Adhesion of Enamels to Iron*

By J. WHITE, B.Sc., Ph.D., A.R.T.C. (The Royal Technical College, Glasgow)

There are two general ways in which materials can adhere to each other:— (1) By "gripping" on the micro or macro scale as the result of a purely mechanical interlocking due to irregularities in the common surface of contact, or (2) by the interplay of attractive forces exerted by the actual atoms or molecules of the substances. Evidence of the first type of adhesion should be obtainable by visual examination of the interface at sufficiently high magnifications. As regards the second type, atomic forces may give rise to chemical reaction, to alloying (as in the application of one metal to another), or to the more general phenomena of interfacial attraction or adsorption. Only in the first two cases is visual evidence liable to be obtainable, and then only if reaction has proceeded to an appreciable extent. All of these reactions can, and do, produce strong adhesion, but they are specific in nature, and depend on the identity of *both* the substances in contact. For example, a liquid may wet one solid readily, while it sits up in beads on another.

There is considerable evidence to indicate that enamels completely free from reducible oxides have no very marked tendency to wet iron so long as the surface is free from oxide. Qualitative experiments were carried out to test this hypothesis. It was found that, when simple borate and silicate glasses were fused on the surface of electrolytic iron in complete absence of oxygen, beads were formed which sat up on the surface of the metal indefinitely. By the use of a sealed tube fitted with a glass window, it was possible to keep the beads under observation continually, and even to measure the contact angle between them and the metallic surface.† This angle was found to be approximately 72 deg. At room temperatures the adhesion of these beads was found to be very slight, and they were readily detached from the metal, leaving a clear, bright surface underneath. Though not absolutely conclusive, due to the simple nature of the glasses taken, these tests seem to indicate that intrinsically the interfacial attraction between iron and enamel glass is not very marked. (This does not necessarily hold for all metals. Gold, for instance, can be obtained dispersed in the colloidal state in certain glasses, and that probably indicates a fair degree of interfacial attraction between the metal and glass. Some metals have even an appreciable solubility in glasses.)

Theories on Adhesion of Enamels to Iron

Perhaps the most striking feature of the literature on the adhesion of enamels to iron is the lack of any general agreement, not only between the theories propounded, but also between the observations of different investigators. This arises, probably, from the complexity of the subject, and the large number of variables involved, many of them of, as yet, incompletely understood significance. At the present time the most likely possibilities appear to be the following:—

(1) Adhesion is the result of mechanical gripping. The chief protagonist of this view is King. In a long series of researches he has sought to establish, from visual evidence, the existence of a mechanical bond at the enamel-metal interface. In particular, he claims to have established the existence of metallic dendrites projecting from the metal surface into the enamel layer, the presence of these being necessary to ensure good adherence. He further suggests that the adhering oxides operate mainly by promoting the formation of these dendrites. One weakness of the purely mechanical theory is that in certain cases very good adhesion has been found to be associated with a more than usually smooth interface, and cases are on record where the addition of adhering oxides increased the smoothness of the interface while improving the adhesion.

(2) The so-called electrolytic theory takes the view that the adhering oxides are oxides of metals which, by virtue of their position in the electromotive series, are replaceable from their compounds by iron, and are thus plated out or deposited at the metal surface, giving an intermediate layer to which the enamel adheres. Nickel and cobalt are correctly situated in the table to allow of this, since they occur lower in the series than iron, but manganese is not, since it occurs higher than iron. Again, if the position in the electromotive series were the only criterion, cobalt oxide should promote adhesion to chromium as well as to iron, whereas Kautz found that cobalt-oxide enamels had very poor adhesion to chromium. To overcome these objections it has been suggested that the ordinary series may not hold at high temperatures in borosilicate melts, since it was actually developed from consideration of aqueous solutions. At the moment this does not seem capable either of proof or disproof, and, as an assumption on which to base a theory, amounts almost to "begging the question."

(3) Still another theory, which has recently received considerable support, is that a layer of iron oxide is necessary at the interface, this layer being capable of adhering firmly to the metal on one side and to the enamel on the other. The action of cobalt oxide, it has been suggested, is to facilitate the formation of this layer. The directly opposed view, that cobalt oxide increases the solubility of iron oxide in the enamel glass and thus promotes the cleansing of the surface from oxide, has also been put forward, however! Recent evidence suggests that it may well play both of these apparently contradictory parts.

A great number of other theories have been proposed but most of them, critically considered, are modifications of, or are embodied in, one or other of the above views.

Part Played by Oxygen in the Enamelling of Iron

No matter what be the exact mechanism of adhesion, it is certain that the oxygen of the muffle atmosphere, affecting, as it does, the surface of the metal, must have a pronounced effect, beneficial or otherwise. Several writers have recently drawn attention to this aspect of the question. Dietzel and Meures[1] have shown that during the early stages of firing, a thin but well-developed scale layer forms on the surface of the metal under the enamel. When the enamel was just beginning to sinter, this layer, on their samples, had attained a thickness of 5 to 7 microns. When the enamel had reached the stage of smooth fusion it had increased to a thickness of 7 to 10 microns. On uncovered portions of the same samples when these stages were reached the scale thickness was 10 microns and 20 microns respectively. This scale layer, formed during the initial stages of firing, must have a considerable effect on the interactions between enamel and metal during the later stages of firing. Concerning the part played by the atmosphere during this later period, when the enamel is fused, there has always been some confusion, and it has occasionally been stated that the supply of oxygen to the surface of the metal then ceases.

The recent work of Dietzel and Meures and of Kautz[2] indicates that this is not so. The former workers investigated the effect of prolonged fusion on iron of enamels free from adhering oxides. They found that the reactions taking place after fusion could be divided into three stages. During the first stage, the initial scale on the metal dissolved in the enamel glass, which acquired a greenish coloration, the iron oxide content of the enamel being mainly in the ferrous condition. During the second stage, the total iron content of the enamel glass was increased, and at the same time an increase in the proportion of ferric iron to ferrous iron took place, until a time was reached when the enamel became saturated with Fe_2O_3, which separated as minute crystals, the enamel being then almost black in colour. At the same time a second scale began to form on the surface of the metal and good adhesion was obtained even though no adhering oxides were present. During the third stage ferric-oxide crystals appeared, giving rise to copperheads, and the enamel was over-oxidised.

The observations of Kautz confirm and elaborate these findings. He claims that for good adhesion the original oxide scale must be completely removed by solution in the enamel glass. This begins to take place as soon as the enamel fuses. At the same time the rate of supply of oxygen to the metal surface is slowed down so that rate of solution of oxide exceeds the rate of formation of oxide and scale is completely removed. Meanwhile the iron oxide content of the enamel is continually increasing, iron in both ferrous and ferric states being present, the latter being formed by atmospheric oxidation. As the iron content increases the rate of oxygen diffusion through the enamel increases until at last a stage is reached when a new scale begins to form. The thickness of this second oxide layer is shown by Kautz's photomicrographs to be approximately 3×10^{-5} in. and its presence is always associated with good adherence. The reason for the different functions of the two oxide layers is probably to be attributed to the different conditions under which they are formed. The first scale is formed by the direct attack of atmospheric oxygen on the surface of the metal.

* Paper read before the Scottish Section of The Institute of Vitreous Enamellers.

† For the method see Barrett and Taylor, Journal of the American Ceramic Society, 1936, 15, p. 39.

The mechanism of such attack and the characteristics of the scale formed are fairly well understood. Below 570 deg. C. Fe_3O_4 is the stable oxide in contact with metallic iron. Above 570 deg. C. FeO is stable, but the conditions governing the formation of thin scales are such that it is found only in a thin layer adjacent to the iron, the bulk of the scale being Fe_3O_4. Such a scale has no very marked adherence to the metal and flakes off fairly readily. The second oxide layer is formed under entirely different conditions. The fused enamel layer slows down and regulates the oxidation of the surface, while, at the same time, the enamel is tending to remove the oxide as it forms by solution.

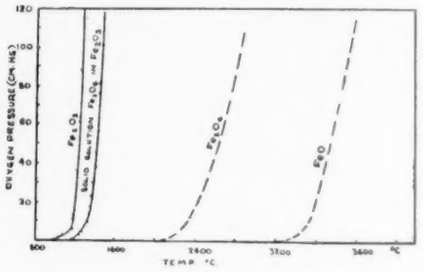


FIG. 1.—DISSOCIATION PRESSURE CURVES OF IRON OXIDES. SOLID LINES: EXPERIMENTAL DATA, WHITE, GRAHAM AND HAY. BROKEN LINES: BY CALCULATION.

Only when the rate of the former reaction exceeds that of the latter can any permanent scale form, and, when it does, it is very thin and is probably mainly ferrous oxide. It is quite possible that such a scale may adhere strongly to the iron surface. It is well known that thin oxide films on metals like aluminium and chromium are very stable and adhere very tenaciously to the metal. The apparent non-adherence of the oxide layers on metals like iron appears to be mainly due to the bulky nature of the oxides, which causes disruptive stresses in the scale layer as soon as it has reached finite thickness.

Dietzel and Meures,[3] as a result of a later investigation, have suggested another possible function of the iron oxide formed at the enamel-metal interface. They have shown that the presence of iron oxide increases the thermal expansion of enamel glass, the amount of the increase being such that the concentration of iron oxide in the enamel glass at the interface is just sufficient, when good adherence is attained, to give a coefficient of expansion practically coincident with that of the metal. They suggest that this explains why most ground-coats have initially, as applied, a markedly lower coefficient of thermal expansion than the metal.

Mechanism of Oxygen Transfer through the Fused Enamel

The mechanism of oxygen transfer through molten silicate melts to an underlying metal has been extensively studied in connection with the so-called "gas oxidation" occurring in the open-hearth steel furnace. There are two possible ways in which such diffusion can occur: (1) through ordinary "physical" solution of the oxygen in the molten silicate, or (2) by the action of compounds (oxides) in the liquid which are capable of oxidation to a higher state by atmospheric oxygen, this higher state being unstable in contact with the metal and consequently undergoing reduction at the silicate-metal interface. It is possible that both of these processes play a part, but the second is probably much the more important of the two. In the open-hearth steel furnace iron oxide is the active agent in effecting transfer of oxygen through the slag, though under certain conditions manganese oxide may also play a part. Both iron and manganese have more than one oxide, and in both cases at high temperature in the furnace atmosphere the tendency is for one of the higher oxides to be formed.

On the other hand, in contact with metallic iron at these temperatures, only the lower oxide is stable. Hence a cyclic oxidation and reduction process is set up, resulting in a continuous flow of oxygen through the slag, with resultant oxidation of the metal. In this connection much research on the relative stabilities of the oxides of iron has been carried out. Fig. 1 shows the dissociation pressure curves of these oxides, the solid lines being based on experimental determinations,[4] the broken lines on theoretical calculations. These curves indicate the stability ranges of the various oxides under varying conditions of temperature and oxygen pressure.

In the molten state iron oxides are soluble in one another, and under any conditions of temperature and oxygen pressure an equilibrium relationship between ferrous oxide and ferric oxide is always reached. This relationship is a continuous function of the oxygen pressure and temperature over the melt, the ferric oxide content being increased by a rise of pressure or by a fall in temperature. Fig. 2 shows an isotherm giving the relationship between the ferrous oxide content and the oxygen pressure in an iron oxide melt at 1,575 deg. C.[5] The equilibrium has also been studied in composite melts, notably in melts containing CaO and SiO_2. The effect on the equilibrium is shown in Fig. 3. CaO displaces the equilibrium towards higher ferric oxide contents while SiO_2 has the opposite effect. It is evident that these additions do not act merely as diluents, but that compounds are present in the liquid melts. These compounds, however, are partially dissociated in the liquid state, and free iron oxide is always present, the relationship between ferrous and ferric oxide being again a function of temperature and oxygen pressure.

It is highly probable that the mechanism of oxygen transfer suggested above was also operating in the fused enamel layers studied by Dietzel and Meures and by Kautz. The active agent would in these cases also be iron oxide dissolved by the enamel glass from the primary scale on the metal. In the case of enamels as normally fired the time available for the operation of such a mechanism to operate may seem very short, but it has been found in practice that melts containing iron oxide adjust themselves to the oxygen pressure over them very rapidly. Further, it should be remembered that the enamel layer is of little depth. Against this may be reckoned the comparatively viscous nature of the fused enamel, but in this connection it may be pointed out that it is not necessary to postulate diffusion of the iron oxide molecules backwards and forwards through the enamel from one face to the other, since a "handing on" of oxygen atoms from one oxide molecule to another is possible.

An attempt was made to measure quantitatively the rate of oxygen diffusion through a glass layer to the surface of iron submerged in it. A square of polished electrolytic iron 2.6 square centimetres in area was submerged in a flat platinum vessel under a layer of a simple glass a quarter of an inch deep. The initial fusion of the glass was carried out in a reducing atmosphere to prevent the formation of iron oxide before the metal was covered by the glass. The vessel was then suspended by a platinum wire in a furnace at 950 deg. C., the upper end of the wire being attached to the pan of a balance, and the gain in weight was recorded, while the melt was exposed to the action of the atmosphere. This took place at the rate of 18 milligrammes per hour, and this rate appeared to remain fairly constant for as long as the experiment was continued. The surface of the metal became darker and the glass acquired a greenish coloration, which deepened as the experiment proceeded. An induction period at the beginning of the experiment, before the enamel had acquired an effective

(*Continued on page 440.*)

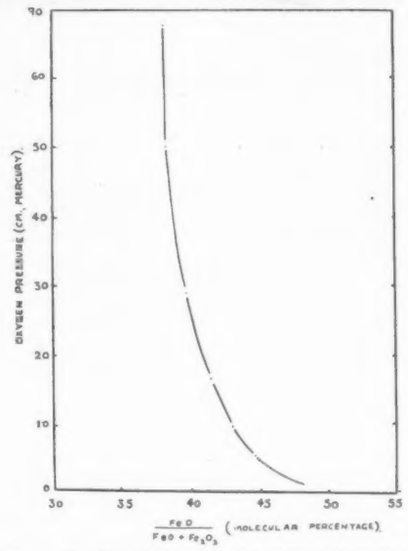


FIG. 2.—DISSOCIATION PRESSURE-COMPOSITION ISOTHERM AT 1,575 DEG. C. FOR IRON OXIDES IN LIQUID MELTS. (KRINGS AND SCHACKMANN.)

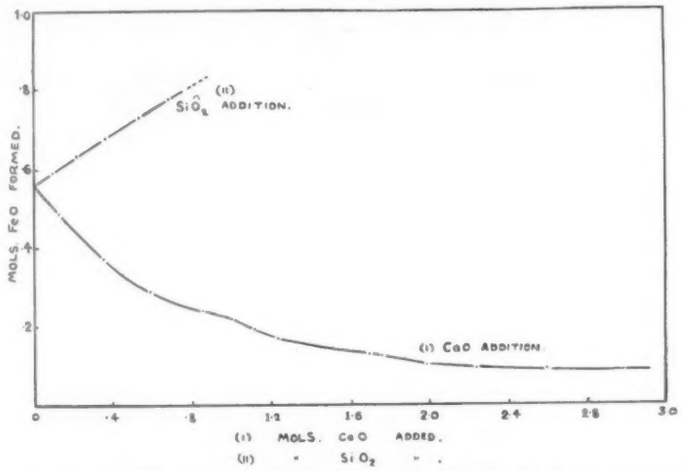


FIG. 3.—EFFECT OF ADDITION OF (1) CaO, (2) SiO_2 ON THE DISSOCIATION OF 1GM. MOL. Fe_2O_3 AT 1,592 DEG. C. AND 15.2 CM. MERCURY PRESSURE OF OXYGEN.

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M 8

iron oxide content, was looked for, but could not be detected with any certainty. It was difficult to prevent completely all oxidation of the metal during the initial fusion, and this may have served to mask the effect if it existed. Glasses containing boric oxide could not be investigated by this method owing to the volatilisation of this constituent. Further attempts made with cobalt oxide in the glass were inconclusive owing to the impossibility of carrying out the preliminary fusion in a reducing atmosphere with this oxide present. Several attempts were made to do so in a really effective "neutral" atmosphere, but time did not allow of the matter being further pursued.

Function of Cobalt Oxide in Promoting Adherence

Kautz has suggested that cobalt oxide may play two parts in promoting adherence. It may increase the solvent power of the enamel for the initial scale. This scale is mainly Fe_3O_4, which, of the three oxides of iron, is the least soluble in enamel glass. Kautz found that with white cobalt-free grounds, even when well-fired, a large amount of the initial scale still persisted. The other suggested function of cobalt oxide is to speed up the rate of oxygen transfer through the enamel, thus facilitating the formation of the secondary scale. It is quite probable that cobalt oxide can play the part of oxygen carrier. Like iron oxide, it can exist in several degrees of oxidation, and there is further a close similarity

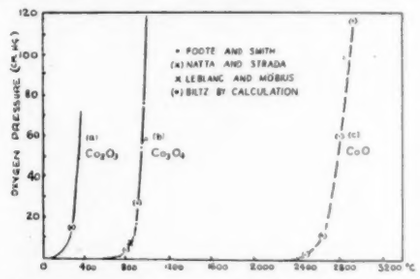

FIG. 4.—DISSOCIATION PRESSURE CURVES OF COBALT OXIDES.

between the corresponding states of oxidation. The stability relationships between the oxides of cobalt have not been so extensively studied as in the case of the oxides of iron, but Fig. 4 summarises the available data, experimental and theoretical, on the dissociation pressures of the three principal oxides.[6]

The data indicate that at enamelling temperatures in air a stage of oxidation approximating to the intermediate oxide will be stable (the oxide being considered as in solution and not in the solid state). In contact with metallic iron, however, reduction will occur to the lower oxide, or even to metallic cobalt, if the data are correct, since cobaltous oxide has a higher dissociation pressure than ferrous oxide, as can be seen by comparing Figs. 1 and 4. This fact, incidentally, may explain the frequently reported precipitation of metallic cobalt near the metal surface. Hence conditions are suitable for the occurrence of an oxidation and reduction cycle of the type previously described. It is further significant that nickel and manganese (the oxides of which are also used to promote adherence) should each have more than one oxide, and that these oxides should be closely analogous and should be of comparable stability to the oxides of iron and cobalt. It may well be that this is the essential function of all the adhering oxides.

With regard to the dendrites observed by King, and stated by him to consist mainly of metallic iron, it is possible that they are merely the natural result of the well-established instability of ferrous oxide. From a consideration of the iron-oxygen thermal equilibrium diagram, it is obvious that ferrous oxide is at least partly dissociated in the liquid state, and it is quite possible that this is also the case when ferrous oxide is dissolved in other substances. Again, even in the solid state, ferrous oxide is unstable below 570 deg. C., dissociating with deposition of metallic iron. Either of these reactions could explain the formation of King's dendrites. The amount of deposition would naturally depend on the concentration of iron oxide in the enamel. It would therefore be expected to occur near the metal surface where the concentration is highest. Further, the oxygen carrying function of cobalt oxide, by increasing the formation of iron oxide, should cause increased deposition in cobalt oxide enamels as observed by King.

Most theories on the adherence of enamels make little attempt to explain adherence to cast iron, and why it is not usually necessary to employ special oxides. The suggestion that purely mechanical gripping plays a bigger part due to the rougher surface of the iron is not supported by many of the photomicrographs of the interface which have been published. Dietzel and Meures found good adherence even in absence of cobalt oxide, provided the firing were prolonged sufficiently to allow the necessary iron oxide to form. In the dry process the grip coat is fired on the metal for a much longer time than is usually given to the ordinary wet-process ground-coat, and a considerable content of iron oxide is possible. Of course, other factors may be involved. Cast iron is a more complex substance than steel, and the scale forming on it is also of a complex composition; for instance, it contains appreciable amounts of SiO_2, and this will influence its behaviour towards the enamel glass.

The "oxide film" theory cannot yet, perhaps, be taken as definitely established, but it is distinctly suggestive, and seems to offer a reasonable explanation of many of the phenomena associated with adherence.

REFERENCES.

1 Dietzel and Meures, Journal of American Ceramic Society, 1935, XIV, p. 35.
2 Kautz, Journal of American Ceramic Society, 1936, XV, p. 93.
3 Dietzel and Meures, Journal of American Ceramic Society, 1935, XIV, p. 37.
4 White, Graham and Hay, Iron and Steel Institute, 1935, **131**, p. 91.
5 Krings and Schackmann, "Zeit. für Electrochemie," 1935, **41**, p. 483.
6 Gmelin's Handbuch der Anorganische Chemie.

(*Concluded from next column.*)

characteristic of the pickling of stainless austenitic chrome-nickel steel in a bath of HNO_3/HCl.

The pickling factors considered are concentration of the acid, temperature of the bath and composition of the material. In pickling carbon steel, a variation of the temperature proves to have a considerably greater effect on the rate of pickling than an alteration in the concentration of the acid. With the same acid concentration and the same bath temperature, the rate of pickling during the period of oxide dissolution is greater when pickling in an HCl bath than in an H_2SO_4 bath, and during the period of metal dissolution the rate of pickling in an HCl bath is more closely dependent on the concentration of the acid and the temperature of the bath than when pickling in an H_2SO_4 bath. At low concentrations and low temperatures, the rate is accordingly lower for the HCl bath, becoming higher with increase in concentration or temperature. Owing to the greater tendency to oxide dissolution, the period of pure pickling in an HCl bath is shorter than in an H_2SO_4 bath. The carbon content does not appear to have any effect worth mentioning upon the rate of pickling during the period of oxide dissolution. During the period of the dissolution of the metal, the difference in the rate of pickling in the case of varying carbon contents is, on the other hand, dependent upon the concentration of the acid and the temperature of the bath, so that it may be as much as 20 times greater in the case of steel with high carbon contents than with steel with low carbon contents.

In pickling stainless austenitic chrome-nickel steel in a bath of HNO_3-HCl, the HNO_3 concentration has a marked effect, and the HCl concentration a slight effect, on the rate of pickling.

Some Important Factors in the Pickling of Steel

G. WALLQUIST, R. LINDBERG and F. W. VON WALTER, in "Jernkontorets Annaler," describe the results of a research programme for the investigation of a number of the principal factors playing a part in the pickling of carbon and stainless steels. As is well known, in the hot working and heat-treatment of iron and steel, a more or less thick layer of oxide, always comparatively hard, is formed on the surface of the metal. This layer has in many cases to be removed, which may be effected in several ways; of the various methods favoured, the purely chemical method of pickling is very largely employed in the iron industry, owing to its simplicity and comparatively low cost. In a pickling process, the rate of pickling plays an important part, and the factors influencing this rate require careful investigation and determination in most cases. To this end a number of tests for the purpose of determining the effect of certain important factors on the pickling rate, when pickling different qualities of steel, have been carried out in the Swedish Royal Technical College's department for the working and treatment of iron.

The principal factors which affect the rate of pickling—indicated in the tests as loss in weight per minute in grms. per sq. m.—are the chemical composition and nature of the articles pickled and of the oxide adhering to them, the chemical composition and the temperature of the pickling bath, the stirring of the bath and also the addition of inhibitors. The effect of these factors is discussed by the authors. In industrial pickling processes, it is the material to be pickled and also the properties of the pickling bath, as determined by composition and temperature, which more particularly govern the course of the pickling, and these pickling factors have been made the subject of a closer study in a series of pickling tests. Three qualities of steel were tested, two being carbon steel with 0.15 and 1.10 per cent. carbon respectively, and also a stainless steel with 0.09 per cent. carbon, 18.5 per cent. chrome and 7.7 per cent. nickel, in the form of hot-rolled steel plates, from which test-pieces measuring 60 by 50 by 2 mm. were cut. The effect of the acid concentration and the bath temperature was ascertained by means of pickling the carbon steel in a bath with concentrations of 5, 10, 20, 40 and 80 per cent. sulphuric acid by weight, at temperatures of 20, 40, 60, 80 and 95 deg. C., and also with concentrations of 5, 10, 20, 30 and 37.32 per cent. by weight of hydrochloric acid at the same temperatures. The austenitic chrome-nickel steel was tested in various mixtures of nitric acid and hydrochloric acid at temperatures of 20, 40, 60 and 80 deg. C. The pickling action was determined as a function of the time by interrupting the process and ascertaining, by weighing, the loss of weight of the test-pieces pickled, after which pickling was continued. Following a survey of the theory of pickling, the authors deal with the results obtained in the tests, which illustrate the mechanism of the pickling process. The actual pickling may be divided into three different stages, the stage of dissolution of the oxide, the transition stage and the stage of dissolution of the metal, which have been called "pickling course 1 to 6" by the authors. They are compared graphically with the loss of weight per unit of surface, the loss in weight in grms. per sq. m. being plotted as ordinate and the time in minutes as abscissa. The more satisfactory pickling courses 1 and 2, with a big difference in the rate of pickling during the periods of oxide and metal dissolution and a relatively short transition period, are obtained when pickling carbon steel in a bath of H_2SO_4 and a bath of HCl, while pickling course 3, with approximately the same rate of pickling during the two periods, is

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The Week's News in Brief

Trade Talk

THE DIRECTORS of Follsain Syndicate, Limited, are offering to shareholders £50,000 4½ per cent. first mortgage convertible income debenture stock at par.

THE LANARKSHIRE STEEL COMPANY, LIMITED, are to build another 60-ton open-hearth furnace at their Motherwell works, in order to keep pace with the capacity of the rolling mills.

THE ANNUAL DANCE of Ley's Malleable Castings Company, Limited, and the Ewart Chainbelt Company, Limited, at the Assembly Rooms, Derby, was attended by over 200 people.

INTERNATIONAL COMBUSTION, LIMITED, Derby, have on hand orders that will provide work at full capacity for the next two years. Contracts of the total value of £750,000 have recently been secured.

A FIRE broke out in the pattern storeroom, foundry and garage at the works of Samuelson's Agricultural Implements, Limited, Cropredy, Oxon, on November 26. The cost of the damage is estimated at over £1,000.

THE STANTON IRONWORKS COMPANY, LIMITED, and the Staveley Coal & Iron Company, Limited, have given notice of withdrawal from the British Iron and Steel Federation. Both Stanton and Staveley are mainly interested in cast-iron pipes and as pig-iron producers will, presumably, remain in association with the Federation through the appropriate affiliated organisation, though relinquishing their individual membership.

LAMBERTON & COMPANY, LIMITED, of Coatbridge, have recently obtained several important orders for steelworks equipment, including a cold-rolling plant for a continuous sheet mill for John Summers & Sons, Limited, Shotton. This will be the biggest plant of its kind in Europe. The housing castings, weighing over 80 tons, will be larger than those now being made for a similar mill for Ebbw Vale. Some of the castings were obtained in Sheffield, but the firm have also bought from Germany.

THE INDUSTRIAL WELFARE SOCIETY and the National "Safety First" Association are attempting to establish a film library from which firms can hire safety films for exhibition to their employees. The films will be of three kinds: general propaganda films designed to make employees safety conscious; instructional films showing employees the safe way of performing specific operations; and technical films showing the latest developments in safety engineering, such as new types of guards. A joint committee has been set up, and will collect, as the nucleus of its library, as many as possible of the industrial safety films already in existence in this country. It is planning also to make one or two general instructional safety films.

Cupola Practice in Textile Engineering Works

(*Concluded from page* 436.)

At 10.20 a.m. the men add six more shovels of coke, and allow the fire to burn until 11.15 a.m. Then they fill up with coke to within a few inches of the firebricks in the arch of the firebars. The fire is made brisk by poking; at 1.0 p.m. this is repeated, but no coke is added. This is done again at 3.30 p.m., but this time the men add six or seven shovels of coke. At 4.45 p.m. poking is again resorted to. At 5.0 p.m. the men close the slides to within ½ in. and the dampers to within 2 to 3 in. from being closed. Now they put on coke until the firebox is just over half full. The ovens can now be left for the night and at 6 a.m. next morning the fire will be burnt down, ready for cleaning out and for another day's work. All this sounds far more complicated than it actually is, and it is found to work extremely well. In fact, the author doubts if he could get any better or cheaper service from a modern gas fired annealing oven system. There are installed modern gas ovens for annealing steel rings, rollers, etc. They have been tried out for annealing cast iron, but, up to the present no improvement over the coke ovens has been noted. The total coke consumption per oven per 24 hour day is of the order of 80 shovelfuls.

Personal

MR. LOGAN TAYLOR has been appointed chief electrical draughtsman with the Carron Iron Company, Falkirk.

MR. H. BUNTING has changed his home address from 82, Otter Street, Derby, to 11, North Avenue, Darley Abbey, near Derby.

MR. WILLIAM LOMAS, chairman of J. & J. Dyson, Limited, firebrick manufacturers, of Stannington, Sheffield, celebrated his 95th birthday on November 24.

MR. WILLIAM E. DOBSON has been appointed a director of British Pigirons, Limited, whose address is Abbey House, 2, Victoria Street, Westminster, London, S.W.1.

MR. W. WILSON HAMILL has been appointed managing director of Henry Meadows, Limited, engineers, of Wolverhampton, in succession to the late Mr. Henry Meadows.

DR. W. D. JONES was the host at a dinner-party held at the Holborn Restaurant, London, last Saturday, to celebrate the publication of his book on "Powder Metallurgy," and to acknowledge the help that he had received during its preparation.

LORD RIVERDALE OF SHEFFIELD has been appointed chairman of the Advisory Council to the Committee of the Privy Council for Scientific and Industrial Research in succession to the late Lord Rutherford of Nelson, and Sir William H. Bragg has been appointed a member of the Advisory Council.

Will

ROLLINSON, SAMUEL, of Radcliffe-on-Trent, engineer and iron and brass founder £11,667

Obituary

MR. VICTOR REICHWALD, Secretary of the British Malleable Tube Association, died suddenly in Berlin on November 24, in his 60th year. The funeral took place on Monday at Tandridge, Surrey.

THE DEATH occurred last week of Mr. Vernon Percival Gamon, J.P., aged 54, a director of Nasmyth, Wilson & Company, Limited, locomotive engineers, of Patricroft, near Manchester. He was a director of the Manchester and District Engineering Employers' Federation.

WE REGRET to announce the death of Mr. L.-E. Dady, an outstanding figure in French foundry circles. For seventeen years he acted as President of the Association Amicale et Mutuelle de Fonderie, and was a Vice-President of the Association Technique de Fonderie. His work on behalf of these bodies was recognised by the Government, and he was created a Chevalier of the Legion of Honour.

THE FUNERAL took place on Tuesday of Mr. George Adolphus Beal, a director of Edward Deane & Beal, Limited, of Monument Street, London, of Hattersley Bros., Limited, Queen's Foundry, Swinton, and of Autocontrol Boilers, Limited, of Victoria Street, S.W. Mr. Beal, who died suddenly in Germany where he was on holiday, was 65 years of age. He was a member of the Council of the Combustion Appliance Makers' Association.

New Company

(From the Register compiled by Jordan & Sons, Limited, Company Registration Agents, 116 to 118, Chancery Lane, London, W.C.2.)

Brytallium Metal Company, Limited, 26, Brazennose Street, Manchester.—Capital £4,000. Directors: H. Harwood, J. Turner and J. Wright.

Contract Open

London, S.E., December 10.—400 tons of hematite pig-iron, West Cumberland; 447,800 buckles, iron, tinned, nickel and plain, for the Director-General, India Store Department, Belvedere Road, Lambeth, London, S.E.1. (Fee 10s., non-returnable.)

Book Review

Effect of Impurities in Copper. By S. L. Archbutt, F.I.C., and W. E. Prytherch, M.Sc. Published by the British Non-Ferrous Metals Research Association, Regnart Buildings, Euston Street, London, N.W.1. Price 13s., post free.

The precise effect of those elements which are usually found or may be present in commercial grades of copper has long been a subject of much interest, and, unfortunately, many loose statements have been made. This research monograph will do much to remove many erroneous views, and collates in a manner typical of the best British research work all the reliable knowledge on this subject. It is restrained and reasoned throughout, and no dogmatic statements are made without just and ample proof.

Research work in this field was commenced at the National Physical Laboratory in 1920, and the results of the last 17 years' work, together with all other reliable data published before and since that date, are to be found in this work. From the foundryman's point of view, it is unfortunate that no data regarding the effect of boron and silicon on the casting properties and electrical conductivity have been given, since these two elements are those most generally used where copper castings for electrical purposes are made. Again, the effect of hydrogen and sulphur, and the combined effect of oxygen and hydrogen, only occupy three pages in the book, and it is probable to suppose that these elements have a profound effect on the soundness and physical properties of both cast copper and copper alloys. The book is one essentially for the worker in copper in the comparatively pure and forged or rolled state, but is to be commended as a useful addition also for foundry metallurgists who are interested in the academic side of metallurgy, particularly those concerned with the founding of high-grade copper alloys.

F. W. R.

Forthcoming Events

DECEMBER 6.

Institution of Mechanical Engineers (North-Eastern Branch):—"Modern Cast Irons and Their Application in Engineering Practice," Paper by A. Campion, at Mining Institute, Newcastle-upon-Tyne, at 6.30 p.m.

DECEMBER 7.

Institute of Welding (Leeds and District Branch):—"Substitution of Castings by Welding," Paper by P. L. Roberts, at Technical College Lecture Theatre, Huddersfield, at 7.30 p.m.

DECEMBER 10.

Institute of Welding (Midlands Branch):—"Working Data on the Cutting of Steel by the Oxygen Jet," Paper by N. Daniel and C. E. Durant, at James Watt Memorial Institute, Great Charles Street, Birmingham, at 7.30 p.m.

Institute of British Foundrymen

DECEMBER 7.

Burnley Section:—"Gravity Die-casting of Aluminium Alloys," Paper by A. Palmer, at Municipal College, Ormerod Road, Burnley, at 7.30 p.m.

DECEMBER 9.

London Branch:—Joint meeting with Institute of Metals: "Magnesium Casting Alloys," Paper by A. J. Murphy, at Society of Motor Manufacturers and Traders, Pall Mall, London, S.W.1, at 7.30 p.m.

DECEMBER 11.

Bristol Section:—"Testing of Foundry Sands," Paper by N. D. Ridsdale, at Merchant Venturers' Technical College, Bristol, at 7 p.m.

East Midlands Branch:—Discussion on Gating and Feeding of Castings, introduced by H. J. Beck, T. Goodwin and F. Dunleavy, at Loughborough College, Loughborough, at 6 p.m.

Scottish Branch:—"Refining Steel in a High-Frequency Furnace," Paper by Victor Stobie, at Royal Technical College, Glasgow, at 4 p.m. Annual dinner, at Grosvenor Restaurant, at 6 p.m.

Wales and Monmouth Branch:—Joint meeting with Iron and Steel Institute and Newport Metallurgical Association: Discussion of First Report of Ingot Moulds Sub-committee, at Technical College, Newport, at 6.30 p.m.

West Riding of Yorkshire Branch:—"Production of Certain Iron Castings," Paper by J. Roxburgh, at Technical College, Bradford, at 6.30 p.m.

The Institute of Vitreous Enamellers

DECEMBER 9.

Midland Section:—"Analyses of Cast Iron suitable for Vitreous Enamelling," Paper by H. Cowan, at Chamber of Commerce, New Street, Birmingham, at 7.30 p.m.

Northern Section:—"Carborundum—Its Origin and Uses," illustrated by cinematograph, at Queen's Hotel, Manchester, at 7.30 p.m.

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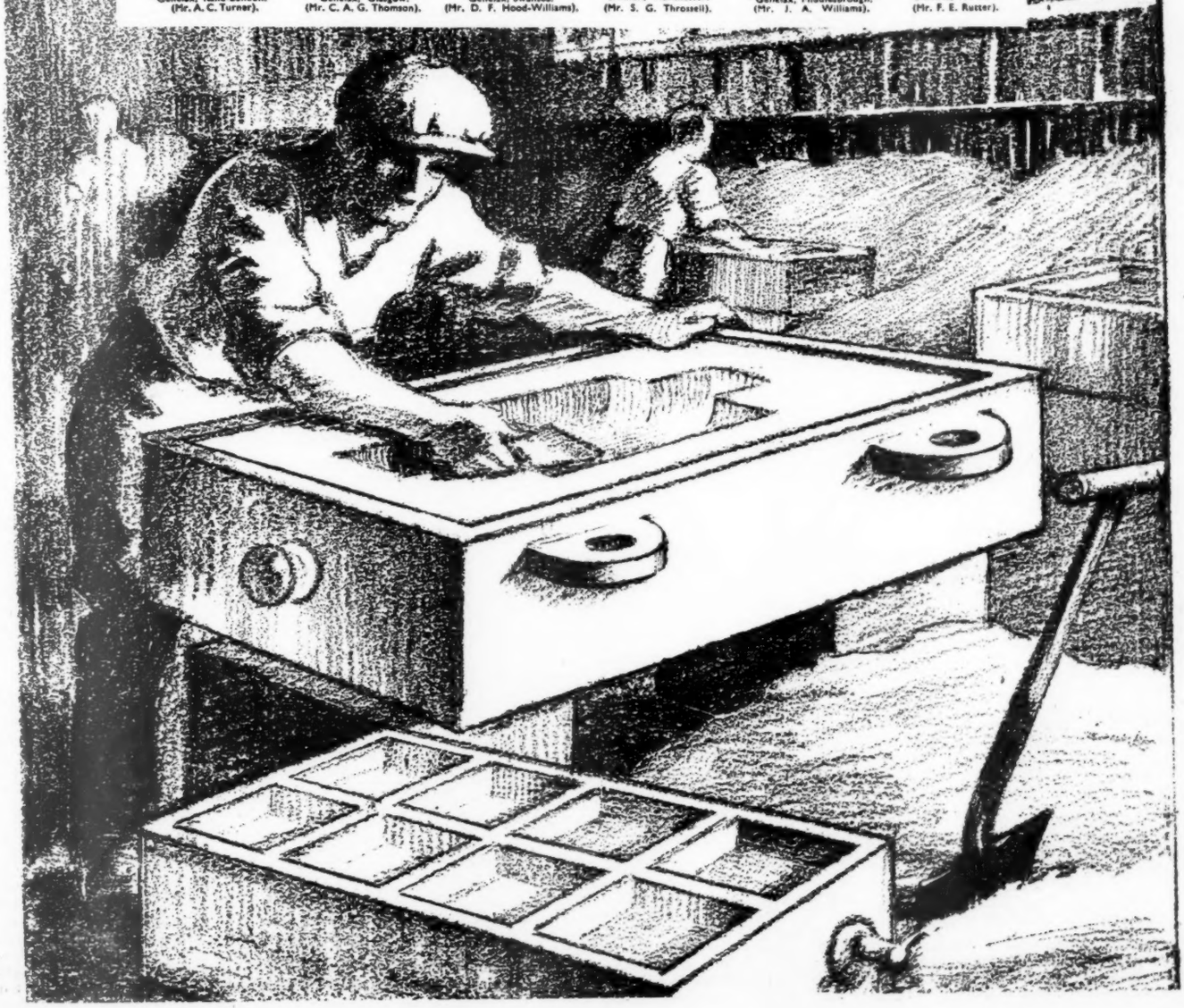


Raw Material Markets

There does not appear to have been any actual rush to enter into new contracts for pig-iron and hematite since the announcements last week of the makers' price decisions, but interest has not been lacking and inquiries are certain shortly to mature into contracts. As reported in our last issue, foundry pig-iron prices will be unchanged (except Cleveland iron, which will be 3s. per ton higher in some zones) over the first half of next year, while hematite over the whole of 1938 will be 10s. in excess of the current prices.

Pig-Iron

MIDDLESBROUGH.—Although the supply position at the present time does not facilitate the transaction of further business with Scotland, under the new prices consumers in Falkirk will be able to negotiate on the same price basis as Tees-side users, namely, 109s. per ton. Clydeside trade will be at 112s. As the price of Scottish No. 3 pig-iron is 118s., it will be beneficial for Scottish buyers to go to the Middlesbrough area for their supplies. No. 3 Cleveland G.M.B. is quoted at 106s. for delivery on the North-East Coast up to the end of the year, with No. 1 foundry at 108s. 6d. and No. 4 foundry and No. 4 forge at 104s., all less 5s. per ton rebate. Now that the new hematite prices have been fixed producers should have little difficulty in disposing of their outputs over the first half of the year. Deliveries against old contracts are substantial, while shipments, also, are heavy, but export inquiry has declined of late.

LANCASHIRE.—Contract deliveries are being well taken up in this area, but new business is not particularly brisk, possibly as a number of consumers had already covered their first quarter's requirements before the price decision was announced. While the heavy foundries are very active, the light-castings makers are comparatively quiet. Both textile machinists and jobbing foundries are now better engaged. For delivery to users in the Lancashire zone, offers of Derbyshire and Staffordshire brands of No. 3 iron are on the basis of 114s. per ton, less 5s. rebate, with Northamptonshire at 112s. 6d. and Derbyshire forge iron at from 109s. to 111s. according to the class of user. Scottish foundry iron is scarce and is quoted nominally at around 140s., delivered in the Manchester district. Hematite is at 131s. for West Coast brands and 130s. 6d. for East Coast, both delivered in the Manchester district.

MIDLANDS.—Consumers in this area now have the opportunity to enter into new business, and, as supplies are plentiful, much activity in this respect is expected to result. Makers have actually invited users in other districts to negotiate with them for further supplies. For delivery to Birmingham and Black Country stations, Derbyshire, Lincolnshire and North Staffordshire No. 3 is quoted at 111s., and Northamptonshire at 108s. 6d., less 5s. per ton rebate. Forge pig-iron is currently quoted at 5s. below the foundry iron quotation, but after December 31 the reduction will be only 3s. Foundries can purchase forge iron at 3s. less than the price of foundry iron at present, but after the end of the year the price will be 1s. only below No. 3. Pig-iron stocks at the furnaces are very low at present. The demand for special irons is heavy. Low-phosphorus iron is quoted between £6 7s. 6d. and £6 15s., but an increase is anticipated shortly. For delivery to Birmingham and district, East Coast No. 3 is quoted at £6 13s. 6d. and West Coast mixed numbers at £6 14s. 6d., less 5s. per ton rebate. Refined iron is at a minimum of £8 2s. 6d.

SCOTLAND.—Pig-iron remains in short supply and deliveries do not always constitute the full contract tonnage. Scottish No. 3 foundry iron is quoted at 118s. per ton at furnaces, with No. 1 at 120s. 6d. Overtime working at the steelworks is general and heavy deliveries of pig-iron are being taken up. Steel-making irons are quoted at 123s. for mixed numbers of hematite, 107s. 6d. for Scottish basic and 100s. for English and Indian basic, all less 5s. per ton rebate.

Coke

The foundry-coke market remains very firm. For delivery to Birmingham and Black Country stations, best Durham coke is quoted at a minimum of 55s. 9d., while Welsh coke varies between 55s. and 65s. per ton, according to quality. New business is quieter. In the case of Durham coke, most producers are willing to sell up to the end of 1938, while consumers generally are not disposed to go further ahead than the end of the winter months, which they have already done.

Steel

With the prices of most descriptions of steel fixed for a long period ahead, steady conditions have developed in the markets. Consumers continue to exert pressure to secure supplies, and the record output of steel is apparently insufficient to satisfy all the requirements of the market, although the makers appear to be making some headway in reducing the heavy accumulations of undelivered orders. In most cases the steelworks have enough work on hand to keep them busy for several months. There are no signs of diminution in the demand for semi-finished steel, and the whole production of the British works supplemented by imports is not sufficient to meet the full requirements of the consuming industries. In the finished steel department, a fair amount of business has been placed recently, and negotiations on contracts for far forward execution are proceeding. In this department the question of delivery is again becoming more important than that of price now that quotations have been fixed for the whole of 1938.

Scrap

Consumers of iron and steel scrap remain quite willing to pay current firm prices for supplies and some heavy tonnages are regularly changing hands. Certain grades are more plentiful than others, cast-iron descriptions, especially, being easier. In some cases deliveries of cast iron have been suspended owing to heavy stocks at the consuming plants.

Metals

Copper.—While the industrial demand remains quiet, there have been indications that consumers are desirous of taking up further tonnages. In the United States, some Customs smelters have lowered their price to 10¾ cents per lb. The market continues to be dull, but a more cheerful tone has prevailed on Wall Street and this should soon be reflected in consumers' demands.

Metal Exchange quotations were as follow :—

Cash.—Thursday, £37 11s. 3d. to £37 12s. 6d.; Friday, £37 17s. 6d. to £38; Monday, £40 8s. 9d. to £40 11s. 3d.; Tuesday, £38 13s. 9d. to £38 15s.; Wednesday, £40 2s. 6d. to £40 5s.

Three Months.—Thursday, £37 16s. 3d. to £37 17s. 6d.; Friday, £38 2s. 6d. to £38 3s. 9d.; Monday, £40 13s. 9d. to £40 15s.; Tuesday, £38 18s. 9d. to £39; Wednesday, £40 7s. 6d. to £40 10s.

Tin.—Both producers and consumers are adopting a reserved attitude and the market remains quiet. The future level of the tin quota is still very uncertain, but it would appear that the International Tin Committee at their meeting on December 10 will take rather more drastic action than merely reducing the quota to 85 per cent., as was the original intention. According to an Amsterdam report, it is understood that the sub-committee of the International Tin Committee which has been studying the question of a buffer stock will hold a meeting on December 9, the day before the full meeting of the Committee. It is reported that the Dutch delegates do not anticipate any quick decision on the buffer stock proposals.

With regard to the proposed fusion of the Banka and Billiton tin mines in a new company, the Venit, it is stated in an Amsterdam report that many objections have been raised in the Second Chamber's report on the Bill. It is feared that the Bill will disturb the good understanding between Holland and the Netherlands Indies. The main objection against the details of the fusion is the proportion of 90 to 10 in which the shares of the new company will be distributed among the Government and the Billiton company, and it is also thought that this proportion is unfavourable for Banka.

The November issue of the Statistical Bulletin of the International Tin Research and Development Council, published by The Hague Statistical Office, reveals that tin production in the first nine months of 1937 amounted to 145,600 tons against 127,000 tons in the corresponding months of 1936. In the September quarter as high a figure as 52,100 tons was reached, against 47,600 tons in the June quarter. Consumption of tin in manufacture in the first nine months of 1937 was about 134,000 tons, against 121,000 tons in the corresponding months of 1936; consumption in the tinplate industry was about 52,000 tons and 46,000 tons respectively, and in all other manufactures 82,000 tons and 75,000 tons. In most countries apparent consumption in the year ended September, 1937, was well above that in the preceding year. In France there was a decrease of about 500 tons, and in British India of 140 tons. World tinplate production in September amounted to 361,000 tons, but decreased to 290,000 tons in October (preceding year 340,000 tons). During October, 1937, visible stocks decreased by 204 tons to 21,828 tons, representing 12.2 per cent. of the current annual rate of consumption.

Official quotations were as follow :—

Cash.—Thursday, £180 15s. to £181; Friday, £183 to £183 5s.; Monday, £190 15s. to £191; Tuesday, £185 to £185 5s.; Wednesday, £191 15s. to £192.

Three Months.—Thursday, £180 15s. to £181; Friday, £183 to £183 5s.; Monday, £190 to £190 5s.; Tuesday, £184 15s. to £185; Wednesday, £191 to £191 5s.

Spelter.—The price position has been very weak recently. Demand generally has been fairly satisfactory. The domestic quotation in the United States has decreased to 5.50 cents per lb., East St. Louis, and business has been featureless. The galvanising industry has been compelled to reduce operations at some plants.

Daily market prices :—

Ordinary.—Thursday, £14 15s.; Friday, £15 2s. 6d.; Monday, £15 16s. 3d.; Tuesday, £15 7s. 6d.; Wednesday, £15 18s. 9d.

Lead.—Quite a good tone continues to rule in this market, and consumption is satisfactory. World production of lead during October, as reported by the American Bureau of Metal Statistics, was 166,200 tons, compared with 156,400 tons in September.

Day-to-day quotations :—

Soft Foreign (Prompt).—Thursday, £15 13s. 9d.; Friday, £15 10s.; Monday, £16 6s. 3d.; Tuesday, £15 17s. 6d.; Wednesday, £16 5s.

Scrap.—Consumers' inquiries are frequently being neglected, thus giving rise to reports of shortages. But it is generally believed that sellers are unwilling to dispose of further tonnages in view of the fact that prices are expected to increase in the near future. The present trend, however, continues to be in a downward direction.

Approximate selling prices for old metal:—New aluminium cuttings, £82; rolled, £67; cast, £40; foil, £94 to £98. Copper, £36 to £38; braziery, £34. Brass (clean), £22 to £24. Zinc, £8 10s. Lead, £14 15s. Gunmetal, £37 to £39.

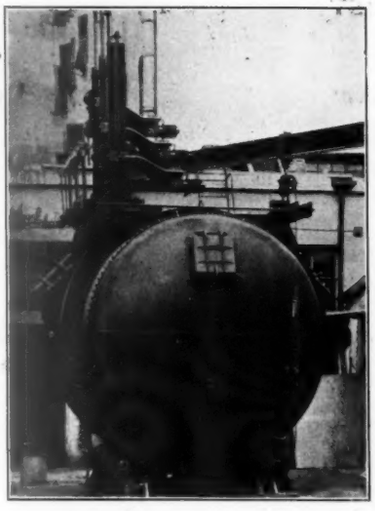
Company Reports

Birmid Industries, Limited.—Net profit for year ended October 31, £71,601; brought in, £2,703; dividend of 10 per cent. and a bonus of 2½ per cent.; writing off preliminary expenses, £5,180; carried forward, £14,340.

Short Bros. (Rochester & Bedford), Limited.—Trading profit for year ended August 31, including royalties, commission, etc., £133,976; net profit after allowing for reserve for taxation, £98,026; available with amount brought in, £177,321; to general reserve, £51,304; staff pensions, £10,000; dividend of 30 per cent., plus a bonus of 10 per cent., £72,000; carried forward, £44,017. Meeting, December 8.

Base Metal Statistics

Quarterly metal statistics for the United Kingdom issued by the British Metal Corporation show estimated consumption of pig lead for the third quarter of this year at 87,000 tons, against 81,000 tons in the preceding quarter. Smelter production was slightly larger at 2,625 tons and stocks in official warehouses rose during the quarter from 6,346 tons to 7,917 tons. Estimated consumption of slab spelter fell from 57,000 tons to 50,000 tons. Smelter production increased slightly to 16,808 tons. Stocks were 20,417 tons, against 19,826 tons. Copper consumption was slightly lower at 80,000 tons, against 82,000 tons in the preceding quarter. Stocks advanced from 18,927 tons to 24,682 tons. Estimated tin consumption was also a little lower at 6,300 tons, compared with 6,500 tons. Smelter production fell by 1,700 tons. Stocks declined from 3,123 tons to 2,614 tons.



METALECTRIC MIXER

For Iron and Steel Alloys . . .

Specialists in Electric Furnaces for melting and all classes of heat treatment, including hardening, tempering, bright annealing, etc.—Special plant for any continuous heat treatment—Industrial temperature indicating, controlling and recording instruments.

3-phase electric mixer
20 ton capacity.

Metalectric-Russ Induction Furnaces for melting non-ferrous metals including aluminium and light metal alloys.

METALECTRIC TAGLIAFERRI FURNACES FOR IRON, STEEL, FERRO-ALLOYS AND CALCIUM CARBIDE MANUFACTURE.

WRITE NOW FOR PARTICULARS AND LEAFLETS

METALECTRIC FURNACES LTD.
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SAND PLANT

ROTARY SCREEN
(*Covers removed*)
CENTRE SHAFT TYPE
CAPACITY 60 tons per hour
with
MAGNETIC BELT CONVEYOR
and
OUTLETS for DESILTING PLANT

SPECIALISTS

Send your enquiries for any FOUNDRY MECHANISATION to the makers :—

COGGON FOUNDRY EQUIPMENT
LIMITED
OVENDEN
HALIFAX

'Phone: 2423.
'Grams: Coggon.

RAW MATERIALS—PRICE LIST

(Wednesday, December 1, 1937)

COPPER

	£	s.	d.
Standard cash	40	2	6
Three months	40	7	6
Electrolytic	44	0	0
Tough	44	13	9
Best selected	45	3	9
Sheets	77	8	9
India	57	6	3
Wire bars	46	8	9
Ingot bars	46	8	9
H.C. Wire rods	49	18	9
Off. av. cash, Nov.	39	7	$4\frac{7}{11}$
Do., 3 mths., Nov.	39	13	$0\frac{3}{11}$
Do., Sttlmnt., Nov.	39	7	$7\frac{4}{11}$
Do., Electro, Nov.	44	18	$7\frac{7}{11}$
Do., B.S., Nov.	44	19	$8\frac{4}{11}$
Do., Wire bars, Nov.	45	16	$9\frac{2}{11}$
Solid drawn tubes			$12\frac{1}{2}$d.
Brazed tubes			$12\frac{1}{2}$d.
Wire			8d.

BRASS

Solid drawn tubes	11d.
Brazed tubes	13d.
Rods, drawn	9d.
Rods, extd. or rlld.	$6\frac{1}{2}$d.
Sheets to 10 w.g.	$8\frac{1}{2}$d.
Wire	$8\frac{1}{2}$d.
Rolled metal	8d.
Yellow metal rods	6d.

TIN

	£	s.	d.
Standard cash	191	15	0
Three months	191	0	0
English	191	15	0
Bars	193	15	0
Straits	195	15	0
Eastern	193	12	6
Banca (nom.)	—		
Off. av. cash, Nov.	190	13	$7\frac{7}{11}$
Do., 3 mths., Nov.	190	5	$1\frac{4}{11}$
Do., Sttlmt., Nov.	190	14	$3\frac{9}{11}$

SPELTER

	£	s.	d.
Ordinary	15	18	9
Remelted	12	15	0
Hard	12	0	0
Electro, 99.9	19	11	3
English	16	10	0
India	14	0	0
Zinc dust	23	15	0
Zinc ashes	6	5	0
Off. aver., Nov.	15	17	$9\frac{9}{22}$
Aver., spot, Nov.	15	16	$1\frac{13}{44}$

LEAD

	£	s.	d.
Soft foreign, ppt.	16	5	0
Empire (nom.)	16	13	9
English	18	5	0
Off. aver., Nov.	16	14	$2\frac{5}{11}$
Aver. spot, Nov.	16	14	$1\frac{19}{44}$

ALUMINIUM

Ingots	£100 to £105
Wire	1/3 to 1/4 lb.
Sheet and foil	1/2 to 1/4 lb.

ZINC SHEETS, &c.

	£	s.	d.		£	s.	d.
Zinc sheets, English	29	0	0	to	29	10	0
Do., V.M. ex-whse.	29	0	0	to	29	10	0
Rods					23	5	0

ANTIMONY

	£	s.	d.		£	s.	d.
English	81	0	0	to	82	0	0
Chinese, ex-whse. (nom.)					66	0	0
Crude, c.i.f.					38	0	0

QUICKSILVER

Quicksilver	13	0	3

FERRO-ALLOYS AND STEEL-MAKING METALS

Ferro-silicon—							
25%	12	10	0				
45/50%	12	0	0				
75%	17	0	0				
Ferro-vanadium							
35/50%	12/8	lb.					Va.
Ferro-molybdenum—							
70/75% carbon-free	4/9	lb.	Mo.				
Ferro-titanium—							
20/25% carbon-free	9d.	lb.					
Ferro-phosphorus, 20/25%	£21	to	£22				
Ferro-tungsten—							
80/85%	9/3	lb.					
Tungsten metal powder—							
98/99%	9/6	lb.					
Ferro-chrome—							
2/4% car.	34	15	0				
4/6% car.	24	5	0				
6/8% car.	24	0	0				
8/10% car.	24	0	0				
Ferro-chrome—							
Max. 2% car.	36	0	0				
Max. 1% car.	38	5	0				
Max. 0.5% car.	41	0	0				
70% carbon-free	10d.	lb.					
Nickel—99.5/100%	£180	to	£185				
"F" nickel shot	£165	0	0				
Ferro-cobalt, 98/99%	8/6	to	8/9	lb.			
Metallic chromium—							
96/98%	2/5	lb.					
Ferro-manganese—							
76/80% loose	£18	15	0	to	19	5	0
76/80% packed	£19	15	0	to	20	5	0
76/80% export	£22	0	0				
Metallic manganese—							
94/96% carbon-free	1/3	lb.					

Per ton unless otherwise stated, basis 2-ton lots.

HIGH-SPEED TOOL STEEL

Finished bars, 14% tungsten	3s. 10d.
Finished bars, 18% tungsten	5s. 0d.

Per lb. d/d buyers' works.

Extras—	
Rounds and squares, 3 in. and over	4d. lb.
Rounds and squares, under $\frac{1}{2}$ in. to $\frac{1}{4}$ in.	3d. lb.
Do., under $\frac{1}{4}$ in. to $\frac{3}{16}$ in.	1/- lb.
Flats, $\frac{1}{2}$ in. × $\frac{1}{4}$ in. to under 1 in. × $\frac{1}{4}$ in.	3d. lb.
Do., under $\frac{1}{2}$ in. × $\frac{1}{4}$ in.	1/- lb.
Bevels of approved sizes and sections	6d. lb.

Bars cut to length, 10% extra.

SCRAP

	£	s.	d.		£	s.	d.
South Wales (West)—							
Heavy steel, best	3	8	6	to	3	11	0
Mixed iron and steel	3	6	0	to	3	8	6
Heavy cast iron	3	8	6	to	3	11	0
Good machinery			3	17	6		
Cleveland—							
Heavy steel, best	3	7	0	to	3	9	6
Steel turnings	2	13	0	to	2	15	6
Heavy cast iron			4	5	0		
Heavy machinery			4	10	0		
Midlands—							
Short heavy steel			4	0	0		
Light cast-iron scrap	3	2	6	to	3	5	0
Heavy wrought iron	4	0	0	to	4	5	0
Steel turnings	2	5	6	to	2	8	0
Scotland—							
Heavy steel, best	3	5	0	to	3	7	6
Ordinary cast iron	4	7	6	to	4	10	0
Cast-iron borings	2	0	0	to	2	2	6
Wrot-iron piling			4	15	0		
Heavy machinery			4	15	0		

London—Merchants' buying prices, delivered yard.

	£	s.	d.
Copper (clean)	33	0	0
Brass	23	10	0
Lead (less usual draft)	13	10	0
Tea lead	11	0	0
Zinc	9	0	0
New aluminium cuttings	71	0	0
Braziery copper	50	0	0
Gunmetal	31	0	0
Hollow pewter	130	0	0
Shaped black pewter	92	0	0

PIG-IRON*

N.E. Coast (d/d Tees-side area)—

Foundry No. 1	108/6
,, No. 3	106/-
,, No. 4	105/-
Forge No. 4	105/-
Hematite No. 1	123/-
Hematite M/Nos.	122/6

N.W. Coast—

Hem. M/Nos. d/d Glas.	123/-
,, d/d Birm.	134/6
Malleable iron d/d Birm.	160/-

Midlands (d/d Birmingham dist.)—

Staffs No. 4 forge	108/-
,, No. 3 fdry.	111/-
Northants forge	105/6
,, fdry. No. 3	108/6
,, fdry. No. 1	111/6
Derbyshire forge	108/-
,, fdry. No. 3	111/-
,, fdry. No. 1	114/-

Scotland—

Foundry, No. 1, f.o.t.	120/6
,, No. 3, f.o.t.	118/-
Cleveland No. 3, Glasgow	112/-
,, ,, Falkirk	109/-
Scottish hem. M/Nos. d/d	123/-

Sheffield (d/d district)—

Derby forge	105/6
,, fdry. No. 3	108/6
Lincs forge	105/6
,, fdry. No. 3	108/6
W.C. hematite	128/6

Lancashire (d/d eq. Man.)—

Derby fdry, No. 3	114/-
Staffs fdry. No. 3	114/-
Northants fdry. No. 3	112/6
Cleveland fdry. No. 3	114/-
Glengarnock, No. 3	140/-
Clyde, No. 3	140/-
Monkland, No. 3	140/-
Summerlee, No. 3	140/-
Eglinton, No. 3	140/-
Gartsherrie, No. 3	140/-
Shotts, No. 3	140/-

(* Prices of hematite and basic pig-iron, and of foundry and forge iron with a phosphoric content of not less than 0.75 per cent., are subject to a rebate of 5s. per ton under certain conditions.)

FINISHED IRON AND STEEL

Usual district deliveries.

[A rebate of 15/- per ton for steel sections, plates and joists is obtainable in the home trade under certain conditions.]

Iron—	£	s.	d.		£	s.	d.
Bars (cr.)	13	5	0	to	13	15	0
Nut and bolt iron	11	12	6	to	12	2	6
Hoops			14	2	6		
Marked bars (Staffs) f.o.t.			15	15	0		
Gas strip			14	2	6		
Bolts and nuts, $\frac{3}{4}$ in. × 4 in.			17	10	0	and up.	
Steel—							
Plates, ship, etc.	11	8	0	to	11	10	6
Boiler plts.	11	18	0	to	12	0	6
Chequer plts.			13	0	6		
Angles			11	0	6		
Tees			12	0	6		
Joists			11	0	6		
Rounds and squares, 3 in. to $5\frac{1}{2}$ in.			12	0	6		
Rounds under 3 in. to $\frac{1}{4}$ in. (Untested)			11	9	0		
Flats—8 in. wide and over			11	5	6		
,, under 8 in. and over 5 in.			11	10	6		
Rails, heavy			10	2	6		
Fishplates			14	2	6		
Hoops (Staffs)			12	4	0		
Black sheets, 24g. (4-t. lots)			15	15	0		
Galv. cor. shts. (,,)			19	10	0		
Galv. flat shts. (,,)			20	0	0		
Galv. fencing wire, 8g. plain			20	5	0		
Billets, soft, 100-ton lots			7	17	6		
Sheet bars			7	15	0		
Tin bars			7	15	0		

PHOSPHOR BRONZE

	Per lb. basis
Strip	$10\frac{3}{4}$d.
Sheet to 10 w.g.	$11\frac{1}{2}$d.
Wire	$12\frac{3}{4}$d.
Rods	$13\frac{1}{4}$d.
Tubes	$18\frac{1}{4}$d.
Castings	$15\frac{1}{2}$d.

Delivery 3 cwt. free.
10% phos. cop. £33 above B.S.
15% phos. cop. £38 above B.S.
Phosphor tin (5%) £30 above price of English ingots.
C. CLIFFORD & SON, LIMITED.

NICKEL SILVER, &c.

	Per lb.
Ingots for raising	8d. to 1/2
Rolled—	
To 9 in. wide	1/2 to 1/8
To 12 in. wide	$1/2\frac{1}{2}$ to $1/8\frac{1}{2}$
To 15 in. wide	$1/2\frac{1}{2}$ to $1/8\frac{1}{2}$
To 18 in. wide	1/3 to 1/9
To 21 in. wide	$1/3\frac{1}{2}$ to $1/9\frac{1}{2}$
To 25 in. wide	1/4 to 1/10
Ingots for spoons and forks	8d. to $1/1\frac{1}{2}$
Ingots rolled to spoon size	11d. to $1/7\frac{1}{2}$
Wire round—	
to 10g.	$1/5\frac{1}{2}$ to $2/0\frac{1}{2}$

with extras according to gauge.
Special 5ths quality turning rods in straight lengths, $1/4\frac{1}{2}$ upwards.

AMERICAN IRON AND STEEL

At Pittsburgh unless otherwise stated.

	Dols.
No. 2 foundry, Phila.	25.76
No. 2 foundry, Valley	24.00
No. 2 foundry, Birm.	20.38
Basic, Valley	23.50
Malleable, Valley	24.00
Grey forge, Valley	23.50
Ferro-mang. 80%, seaboard	102.50
O.-h. rails, h'y, at mill	42.50
Billets	37.00
Sheet bars	37.00
Wire rods	47.00
	Cents.
Iron bars, Chicago	2.40
Steel bars	2.45
Tank plates	2.25
Beams, etc.	2.25
Skelp, grooved steel	2.10
Steel hoops	2.40
Sheets, black, No. 24	3.15
Sheets, galv., No. 24	3.80
Wire nails	2.75
Plain wire	2.90
Barbed wire, galv.	3.40
Tinplates, 100-lb. box	$5.35

COKE (at ovens)

Welsh foundry	42/6
,, furnace	37/6
Durham foundry	38/6
,, furnace	37/6
Scottish foundry	42/6
,, furnace	40/-

TINPLATES

f.o.b. Bristol Channel ports.

I.C. cokes	20×14	per box	23/-	to 24/-
,,	28×20	,,	46/-	to 48/-
,,	20×10	,,	35/3	to 35/9
,,	$18\frac{3}{4}$×14	,,	25/3	to 25/9
C.W.	20×14	,,	20/-	to 21/-
,,	28×20	,,	40/-	to 41/-
,,	20×10	,,	30/9	to 31/3
,,	$18\frac{3}{4}$×14	,,	21/9	to 22/3

SWEDISH CHARCOAL IRON & STEEL

Pig-iron	£12	0	0	to	£13	0	0
Bars-hammered, basis	£20	0	0	to	£22	0	0
Bars and nail-rods, rolled, basis	£19	0	0	to	£20	0	0
Blooms	£18	0	0	to	£19	0	0
Keg steel	£30	0	0	to	£35	0	0
Faggot steel	£20	0	0	to	£25	0	0
Bars and rods dead soft st'l	£19	0	0	to	£20	0	0

All per English ton, f.o.b. Gothenburg.
[Subject to an exchange basis of Kr. 19.39 to £1.]

DAILY FLUCTUATIONS

Standard Copper (cash)

		£ s. d.	
Nov. 25	..	37 11 3	dec. 5/-
,, 26	..	37 17 6	inc. 6/3
,, 29	..	40 8 9	,, 51/3
,, 30	..	38 13 9	dec. 35/-
Dec. 1	..	40 2 6	inc. 28/9

Electrolytic Copper

		£ s. d.	
Nov. 25	..	42 0 0	No change
,, 26	..	42 0 0	,, ,,
,, 29	..	44 10 0	inc. 50/-
,, 30	..	43 0 0	dec. 30/-
Dec. 1	..	44 0 0	inc. 20/-

Standard Tin (cash)

		£ s. d.	
Nov. 25	..	180 15 0	dec. 105/-
,, 26	..	183 0 0	inc. 45/-
,, 29	..	190 15 0	,, 155/-
,, 30	..	185 0 0	dec. 115/-
Dec. 1	..	191 15 0	inc. 135/-

Tin (English ingots)

		£ s. d.	
Nov. 25	..	180 15 0	dec. 105/-
,, 26	..	183 0 0	inc. 45/-
,, 29	..	190 15 0	,, 155/-
,, 30	..	185 0 0	dec. 115/-
Dec. 1	..	191 15 0	inc. 135/-

Spelter (ordinary)

		£ s. d.	
Nov. 25	..	14 15 0	dec. 10/-
,, 26	..	15 2 6	inc. 7/6
,, 29	..	15 16 3	,, 13/9
,, 30	..	15 7 6	dec. 8/9
Dec. 1	..	15 18 9	inc. 11/3

Spelter (Electro, 99.9 per cent.)

		£ s. d.	
Nov. 25	..	18 10 0	dec. 7/6
,, 26	..	18 17 6	inc. 7/6
,, 29	..	19 10 0	,, 12/6
,, 30	..	19 0 0	dec. 10/-
Dec. 1	..	19 11 3	inc. 11/3

Lead (soft foreign, prompt)

		£ s. d.	
Nov. 25	..	15 13 9	dec. 8/9
,, 26	..	15 10 0	,, 3/9
,, 29	..	16 6 3	inc. 16/3
,, 30	..	15 17 6	dec. 8/9
Dec. 1	..	16 5 0	inc. 7/6

Lead (English)

		£ s. d.	
Nov. 25	..	17 15 0	dec. 5/-
,, 26	..	17 15 0	No change
,, 29	..	18 5 0	inc. 10/-
,, 30	..	18 0 0	dec. 5/-
Dec. 1	..	18 5 0	inc. 5/-

A COMPARISON OF SCRAP PRICES

Average Monthly Prices of Cast-Iron Scrap in the Principal Districts in the Years 1931–37

SCOTLAND (Heavy Machinery)—	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly average.
1931..	£ s. d. 2 15 0	£ s. d. 2 15 0	£ s. d. 2 13 3	£ s. d. 2 10 8	£ s. d. 2 9 9	£ s. d. 2 8 3	£ s. d. 2 8 6	£ s. d. 2 7 9	£ s. d. 2 5 6	£ s. d. 2 9 8	£ s. d. 2 14 5	£ s. d. 2 15 9	£ s. d. 2 11 2
1932..	2 15 0	2 15 0	2 12 6	2 10 6	2 7 6	2 5 3	2 4 5	2 3 10	2 4 10	2 4 4	2 4 0	2 4 8	2 7 8
1933..	2 7 0	2 9 3	2 10 8	2 10 5	2 9 5	2 9 3	2 8 6	2 10 9	2 10 4	2 10 7	2 10 10	2 12 4	2 9 11
1934..	2 14 2	2 17 9	2 18 5	2 18 3	2 15 5	2 14 3	2 15 0	2 15 9	2 15 9	2 15 0	2 15 8	2 16 3	2 16 0
1935..	2 15 5	2 15 8	2 15 10	2 16 4	2 16 10	2 17 0	2 16 9	2 16 9	2 17 0	2 16 11	2 19 11	3 2 7	2 17 5
1936..	3 4 8	3 9 10	3 10 11	3 11 10	3 10 8	3 9 10	3 9 2	3 8 9	3 8 11	3 9 2	3 10 "	3 13 3	3 9 9
1937..	3 15 0	4 2 10	4 6 2	4 9 9	4 14 9	4 15 0	4 15 0	4 15 0	4 15 0	4 15 6	4 15 0	—	—

N.E. COAST (Heavy Qualities)—	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly average.
1931..	£ s. d. 2 10 4	£ s. d. 3 9 8	£ s. d. 2 9 7	£ s. d. 2 8 3	£ s. d. 2 6 3	£ s. d. 2 3 8	£ s. d. 2 2 9	£ s. d. 2 1 9	£ s. d. 2 1 0	£ s. d. 2 2 1	£ s. d. 2 9 9	£ s. d. 2 6 6	£ s. d. 2 5 11
1932..	2 6 3	2 5 8	2 3 0	2 0 8	1 19 0	2 1 0	1 15 9	1 15 6	1 15 6	1 15 6	1 17 4	1 19 10	1 19 7
1933..	2 1 1	2 2 2	2 4 9	2 3 5	1 18 9	1 19 6	2 0 0	2 0 0	2 1 3	2 5 8	2 7 10	2 10 1	2 5 4
1934..	2 12 7	2 15 1	2 13 7	2 11 6	2 11 11	2 13 9	2 11 0	2 10 6	2 11 3	2 11 10	2 13 9	2 13 3	2 12 4
1935..	2 12 2	2 13 0	2 12 7	2 13 0	2 12 9	2 12 6	2 12 6	2 12 6	2 12 6	2 12 6	2 12 6	2 16 10	2 12 10
1936..	3 0 0	3 1 10	3 1 8	3 2 2	3 4 6	3 3 9	3 5 9	3 4 1	3 5 11	3 6 3	3 6 3	3 7 10	3 4 2
1937..	3 10 6	3 14 9	4 2 6	4 3 9	4 6 3	4 7 6	4 7 6	4 7 6	4 6 0	4 5 0	4 5 0	—	—

S. WALES (Heavy Cast Iron)—	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Yearly average.
1931..	£ s. d. 2 7 7	£ s. d. 2 8 3	£ s. d. 2 9 9	£ s. d. 2 8 1	£ s. d. 2 6 11	£ s. d. 2 5 2	£ s. d. 2 2 9	£ s. d. 2 2 2	£ s. d. 2 0 11	£ s. d. 2 3 9	£ s. d. 2 7 6	£ s. d. 2 7 10	£ s. d. 2 5 9
1932..	2 7 2	2 6 8	2 6 4	2 5 0	2 4 8	2 0 8	1 19 4	2 1 7	2 1 10	1 18 10	1 19 8	2 2 1	2 2 0
1933..	2 3 4	2 4 6	2 4 6	2 4 1	2 3 5	2 2 8	2 3 7	2 4 8	2 5 8	2 5 9	2 5 7	2 5 0	2 4 5
1934..	2 6 10	2 8 9	2 7 8	2 6 6	2 7 6	2 8 0	2 6 10	2 6 7	2 8 0	2 8 2	2 9 1	2 11 5	2 7 1
1935..	2 11 3	2 11 4	2 11 1	2 11 3	2 12 0	2 11 1	2 11 1	2 11 0	2 12 2	2 13 10	2 14 5	2 14 8	2 11 9
1936..	2 16 3	2 18 7	2 18 9	2 19 2	2 18 7	2 18 7	2 19 0	2 19 0	2 18 9	2 19 0	2 19 2	2 19 0	2 18 8
1937..	3 4 1	3 9 8	3 9 3	3 9 0	3 9 0	3 9 0	3 9 0	3 9 0	3 8 9	3 9 9	3 9 9	—	—

WILLIAM JACKS & COMPANY,

WINCHESTER HOUSE, OLD BROAD ST., LONDON, E.C.2.

CLARENCE CHAMBERS, 39, CORPORATION STREET, BIRMINGHAM.

13, RUMFORD STREET, LIVERPOOL.

PIG REGISTERED TRADE MARK IRON

All grades FOUNDRY, HEMATITE, BASIC, SPECIALS, &c.

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COPPER, TIN, LEAD, SPELTER, ANTIMONY, CHROME ORE.

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ZETLAND ROAD, MIDDLESBROUGH.

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(A remittance should accompany instructions.)

SITUATIONS VACANT AND WANTED

FIRST-CLASS Moulder, green, dry sand, seeks situation. Three years' experience assistant foreman, jobbing, repetition, ordinary, high-duty cast irons. Young, keen, energetic. Guaranteed to get results.—Box 688, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

CAPABLE Young Journeyman, to take working charge of about eight apprentices. Applicant must be a first class craftsman, have some technical knowledge, and be a keen disciplinarian. Only those who consider themselves capable of imparting practical instruction in medium and small green and dry sand work of jobbing nature need apply. State age, wages required, and details of past and present employment to: KAYE & Co. (HUDDERSFIELD), LTD., Moorbottom Ironworks, Huddersfield.

CHARGEHAND Coremaker and Coremakers required for small coreshop of Midland foundry making light repetition castings. District rates and piecework. Continuous work for suitable applicants.—Apply Box 690, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

FOUNDRY Foreman required, thoroughly experienced in producing soft grey-iron castings. Sound organising ability essential, and up-to-date knowledge of modern production methods. State age, experience, and wage required.—Box 686, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

WANTED.—Working Foreman Coremaker, well versed in the latest oil-sand practice. Castings for general engineering. State age, experience, and salary required.—Box 696, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

EMPLOYMENT REGISTER.

Conducted by the Institute of British Foundrymen by courtesy of the proprietors of THE FOUNDRY TRADE JOURNAL.

Correspondence should be addressed to the General Secretary, Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester, from whom full particulars can be obtained of this service.

Any employer wishing to communicate with a candidate should write to the General Secretary, quoting identification number.

FOUNDRY Foreman with thoroughly practical training and experience requires re-engagement. Experience includes general engineering castings up to 20 tons, also repetition work, machine and plate (315)

FOUNDRY or Works Manager. Position required by young man with considerable experience as Manager and Superintendent, including non-ferrous work. Modern production and costing methods. (316)

BUSINESS FOR SALE

£950—Engineering Machine Shop and small Ferrous and Non-ferrous Foundry Plant in working condition. 2,400 sq. ft. under roof. Reasonable rent.—Write only: ENGINEER, 8, Colson Road, Croydon.

FINANCIAL

AN established Scottish Steel Foundry wishing to develop would consider introduction of further Capital, with or without active part in management.—Box 692, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

MACHINERY

CUPOLA wanted. Good second-hand, 4 ft. dia., complete with belt and with drop bottom.—Box 698, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

WANTED.—One Patternmakers' Lathe, 8-in. centres, with well; and one Sand Papering Machine.—Box 694, Offices of THE FOUNDRY TRADE JOURNAL, 49, Wellington Street, Strand, London, W.C.2.

MOULDING Machines for Sale. Bonvillain & Ronceray. Four No. 3A; two No. 5A Also Ketin & Thiriart Motor-driven Sand Preparing Plant. May be inspected at any time.—STREET, c/o AUSTIN MOTOR CO., LTD., Longbridge Works, Northfield, Birmingham.

NEW Dwarf Cupola, to melt 10 to 15 cwts per hr. New Worm-geared Ladles, 5 tons, 25 cwts., 15 cwts. and 10 cwts. capacity. Ungeared Ladles, 15 cwts. and 10 cwts. capacity. Improved Cupola Spark Arresters.—T. DAVIES & SON, West Gorton, Manchester.

SMALL Power Machine for cutting gits off bronze castings. Write for particulars.—TRIONITE, LTD., Cliffe Vale, Stoke-on-Trent.

ELECTRIC CUPOLA BLOWERS (large stock), including two 50-h.p. 3/50/400 volts, 2,900 r.p.m.; Keith Blackman; 12-in. outlet.
30-h.p. ditto; 12-in. outlet.
5-h.p. ditto; 6-in. outlet.
20-h.p. 460 volts d.c., 2,400/1,900 r.p.m.; 10-in. outlet.
EXHAUST FANS (large stock), electrical and belt driven.
ELECTRIC RUNWAY LIFTING BLOCKS:
One 4½-ton 460 volts d.c., Vaughan.
Two 2-ton ditto, Morris.
One ½-ton 220 volts d.c., Morris (as new).
One ½-ton 3/50/440 volts, Aabacas.
Two Reavell Rotary Compressors, 12 lbs. sq. in. pressure; 750 cub. ft. direct-coupled on bedplate to 60 h.p. S.R., 3/50/400 volts motor.
½-cwt. Pilkington Self-contained Pneumatic Hammer.
Geared Foundry Ladles, 9, 4, 3½, 2½ and 1 ton, etc.
AIR COMPRESSORS: 30 in stock in sizes 500 to 20 cub. ft.
ELECTRIC MOTORS: Large stock to suit almost all electric systems.

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'Phone: Broadwell 1359.

THO[S] W. WARD LTD.

15-ton GEARED FOUNDRY CRANE LADLE; excellent condition; cheap.

Four 5-cwt. Pressed Steel FOUNDRY LADLES; 17" dia. x 16" deep.

Three 5-cwt. Pressed Steel FOUNDRY LADLES.

Write for "Albion" Catalogue.

'Grams: "Forward." 'Phone: 23001 (10 lines).

ALBION WORKS, SHEFFIELD.

MACHINERY—*Continued*

SAND MIXERS AND AERATORS.—The "Breakir" Centrifugal Machine is *THE* machine. Outputs 10 cwts. to 8 tons per hr.—W. BREALEY & Co., LTD., Station Works, Ecclesfield, Sheffield.

MISCELLANEOUS

WAX CORE VENTS in 1-lb. rolls; all sizes from $\frac{1}{16}$ in. dia. Best and cheapest. Quick despatch.—WILLIAM OLSEN, LTD., Hull.

QUEBEC YELLOW PINE.—H. R. Hodgson & Co., Importers, 94, Derby Road, Bootle, Liverpool.

FINEST FOUNDRY BLACKINGS AND FACINGS. Pure Ceylon Plumbago (Import direct), Finest Core Gum, White Dust, Parting Powder (Silica free), Pure Ground Carbon and Electrodes. Quality at reasonable prices. Orders repeated. Send for free sample.
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PENNINE WORKS,
HAZLEHEAD, NEAR SHEFFIELD.
Telephone: 128 Penistone. Telegrams: "Facings, Penistone."

'Phone: 287 SLOUGH

Nearly new 600-lbs. capacity oil-fired Morgan Tilting Furnace Price, £80
1,000-lbs. capacity gas-fired semi-rotary IONIDES Melting Furnace; new condition.....Price, £65
500-lbs. capacity Armstrong-Whitworth Rotary Oil-fired Furnace, complete as new. Price, £50
Oil-Sand Mixer, large size, as new Price, £24
Utard jolt squeeze moulding machine 24" square..... Price, £48
One Sand Grab and two Sand Valves complete with hoppers for placing above moulding machines. Cheap

ALEX. HAMMOND, *Foundry Machinery Merchant.*
14, AUSTRALIA ROAD, SLOUGH
BUY FROM ME AND SAVE MONEY!

PETER—WITH ONE EXCEPTION

With one exception Peter is an ordinary little fellow. Chubby, likeable, just five-and-a-half, full of life and fun and on occasions—be it admitted—of naughtiness.

Just now Peter's rather important, for this is his first term at school, and he's grappling with the intricacies of "A B C" and "Twice-Two": difficult subjects to all men of five-and-a-half, but even more difficult in Peter's case because—bad luck—he's totally blind. That's his One Exception.

Peter learns reading, writing, and 'rithmetic through the medium of "Braille"—dull stuff compared with the coloured picture books of most five-and-a-halfs. However, he's a stout lad is Peter, and he's making great progress.

Would you like to know more about him? How, in spite of his "One Exception," he is being educated and, when older, technically trained and usefully employed.

There is a long waiting list of "Peters" throughout the British Isles, for whom training and accommodation must be provided in the immediate future.

Will you help with a donation or annual subscription? Any sum, large or small, will be gratefully received.

Here's a suggestion. Your eyesight is worth 3d a year to you. Send Peter and his handicapped pals 3d for every year you've had it. Now, please, in case it slips your memory. Good idea?

The Chairman,
SCHOOL FOR THE BLIND
(Founded 1838)
SWISS COTTAGE, LONDON, N.W.3